Julien Meyer

Whistled Languages

A Worldwide Inquiry on Human Whistled Speech

With a chapter in collaboration with René-Guy Busnel

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Julien Meyer
Paris
France

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Preface

Around the world, humans whistle their language
Some live in mountains, others in forests
Whistling is used to speak across distances
This means of communication makes a person one with nature
One can express love and every aspect of life
The melody resembles birdsongs
It tells the story of the people, of their lands and of human language.
Extract of a corpus collected by the author with various whistlers.

This monograph addresses a fascinating and little-known language practice based on whistling. Whistling is one of the multiple modes of expression for some local languages. Whistling does not replace but instead complements ordinary speech, often under different circumstances. It profoundly modifies the phonetic system of the local speech: the voice is replaced by a whistle, which carries the information. This drastic transformation consists of the emulation of selected acoustic cues of standard speech. Therefore, whistled speech is adapted both to the structure of each language—namely its syntax, grammar, and phonology—and to the articulatory constraints of whistling. The advantage of this procedure, from the user's perspective, is not only a vastly increased audible range but also, under certain circumstances, a degree of secrecy toward outsiders. This work is a follow-up of a previous monograph on this subject by Busnel and Classe (entitled "Whistled Languages") published in 1976. Thirty-eight years later, a great deal of additional research has been performed, and several discoveries have provided new insights into the phenomenon. As we will show, during the last 12 years, new instances of whistled languages have regularly been found, thanks to extensive fieldwork. Moreover, we now understand better the processes of whistled speech perception. However, with the modernization of the countryside throughout the world, the traditional activities that justify this special speech register are frequently disrupted, and whistled forms of languages have become endangered oral practices.

The description provided in this book consists of an account of the authors' own investigations supplemented by a large pluridisciplinary bibliographical review. The manner in which the various aspects of the subject are described in Chap. 2 (Historical sketch) results from the collaboration between two authors (Meyer and Busnel). The other chapters have been written by Meyer. The original idea to propose this new monograph to the editor came from Busnel. Meyer decided to write it in homage to the different world cultures he visited and to Professor Busnel, who is in his 100th year of life and is still in close interaction with Meyer, following his research with different collaborators around the world. Among these collaborators, Dr. Laure Dentel is the most significant. Other outstanding collaborators are Professor Colette Grinevald, Dr. Fanny Meunier, Dr. Denny Moore and the speakers of various languages. The last 12 years of research on this subject were made possible thanks to the financial support provided by various institutions such as the Centre National de la Recherche Scientifique (BDI-CNRS grant, France), the Fyssen Foundation (Post-doc grant, France), the Endangered Language Documentation Program (Post-doc project IPF0136, SOAS-University of London), the Conselho Nacional de Desenvolvimento Científico e Tecnológico (PDJ grant, CNPq Brazil), the European Union's Seventh Framework Programme for research, technological development and demonstration (EURIAS Fellowship, Lyon Collegium; Marie Slodowska-Curie Fellowship, project Icon-Eco-Speech) and by prizes including a 2006 Rolex Award and the scientific prize of Paris-Jeunes-Aventures (Mairie de Paris).

The general structure of the book makes it accessible to both the general reader and specialists of various domains, with a primary emphasis on linguistic, acoustic, cognitive, ethnologic, and environmental features.

Contents

Chapter 1
Introduction

1.1 Characterization of Whistled Languages

Whistled languages constitute ancient and natural means of telecommunication that permit spoken communication at great distances. This mode of speech is also used for other purposes, such as secrecy, courtship, singing and communication in noisy environments. Whistled speech is always based on a spoken language. Whistled Greek and whistled Gavião are still Greek and Gavião languages but adapted to another speech register, the "whistled mode of speech" (Figs. 1.1 and 1.2). Around the world, whistled forms of languages are usually found in landscapes that predispose humans to relative isolation during their daily activities. The traditional activities most commonly associated to such whistling communications are hunting, hill agriculture or shepherding. Moreover, mountainous or densely vegetated landscapes are the most common natural environments where whistled speech is practiced. Speakers living in such an ecological milieu often find themselves scattered across great distances, unable to hear each other clearly via speaking or shouting. Whistles represent an adapted response to such constraints to maintain coordination and social contact because their acoustic signal is well transmitted in natural environments and can overcome ambient noise much more effectively than a standard or shouted voice, however stentorian (Fig. 1.3). The principle of whistled speech is straightforward: people articulate words while whistling and thereby transform spoken utterances by simplifying them, syllable by syllable, into whistled melodies. Acoustic reduction operates almost exclusively at the frequency level, and it relies on the selection of key salient phonetic cues for the corresponding spoken utterances. Two primary strategies employed to transpose ordinary voiced speech into whistles have been found: one for tonal languages, called pitch-whistling because it emulates in priority the fundamental frequency of the voice (e.g. Fig. 1.2), and one for non-tonal languages, called formant-whistling because it emulates

The original version of this chapter contained errors which have been corrected. These are detailed in the erratum to be found under DOI 10.1007/978-3-662-45837-2_10

J. Meyer, *Whistled Languages*,
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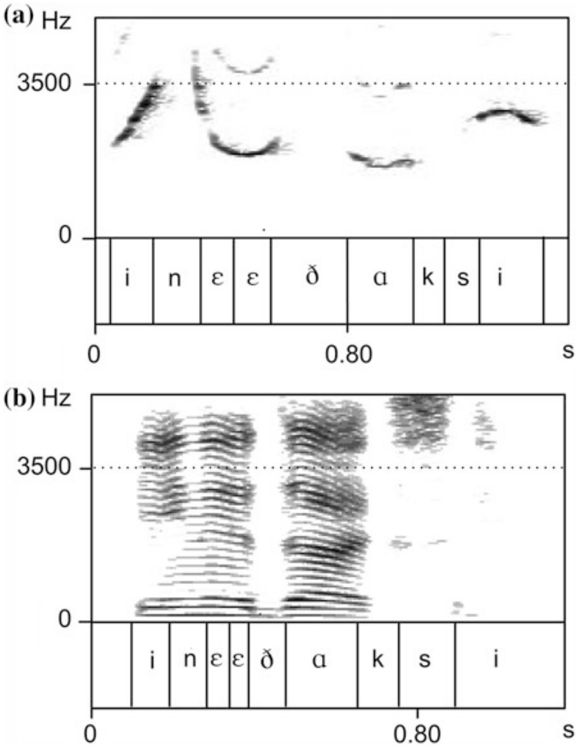

Fig. 1.1 Spectrogram of the Greek sentence 'ειναι ενταξει' [inε εðαksi], or 'ine entaksi' in roman transliteration (meaning '*all right*') in whistled (**a**) and spoken (**b**) speech. Here, the whistled form consists of the emulation of the quality of spoken vowels and consonants (formant-based whistling)

certain aspects of the timbre of the voice that are called formants by linguists (e.g. Fig. 1.1). Some intermediary strategies between these two primary ones have been found, as we will see in Chap. 7. In any case, the resulting whistled signal has a linguistic structure with the same basis as standard speech. One of the most striking aspects of this whistled transformation of words is that the whistled sentences remain highly intelligible to trained speakers, despite a reduced acoustic channel to convey meaning. The whistlers even emphasize that they whistle exactly as they think in their language and that the whistled messages that they receive instantly recall those spoken sentences. In most of the whistled languages, skilled whistlers can effectively whistle any type of dialogue and are even often able to recognize non-stereotyped sentences. However, we will see later that the complexity of the messages that can be transmitted depends on certain structural aspects of the language, such as the complexity of the tonal system for pitch whistling (Chap. 7).

Whistled speech is used when voiced speech fails to fulfill the requirements for communication. All of the whistlers we met considered whistled speech to be an integral part of their local spoken language. The functional role of whistled speech is to complement ordinary speech under certain circumstances, similarly to whispering, shouting or singing. However, whistled speech requires more training than these other speech registers. Once mastered, it is much less demanding in vocal effort than shouting or singing because it does not tire the vocal folds. According to

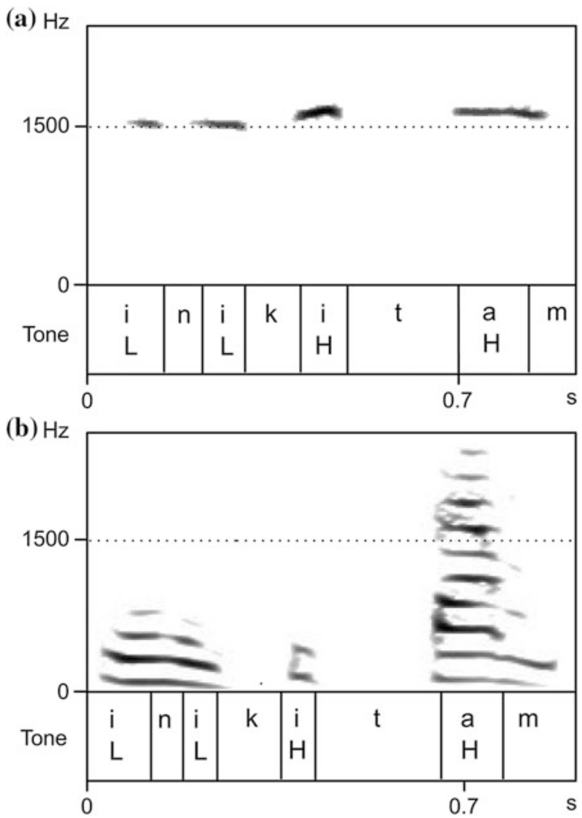

Fig. 1.2 Spectrogram of the Gavião words 'ini kítá̰p' [ini kitam], meaning 'hammock rope', in whistled (**a**) and spoken (**b**) speech. Here, the whistled form consists of the emulation of the pitch of the spoken form (pitch-based whistling)

Busnel and Classe (1976), the process is not essentially different from the whisper-phonation type, which also dispenses with the glottal tone, relying as it does on the excitation of the pharyngo-oral cavity resonance by friction of the breath expelled under pressure. "Not essentially different" should not be taken to mean "to be equated with" because, in the whisper, the complex acoustic cues resulting in the perception of timbre, although subdued, are by no means eliminated. A whistle, however, is a simple oscillation that varies only in intensity, duration and frequency, i.e., loudness, time and pitch. Another important particularity is that in contrast to whispering or most shouting and singing techniques, whistled speech is unintelligible to untrained speakers. Such a limitation is not unique among language practices: it also exists in other drastic transformations of the speech signal, such as soprano singing. However, whistled speech is even more particular because it is not easily identified as a speech act by untrained and unaware speakers, which confers upon whistled speech the distinctive ability to talk unnoticed by strangers. This inherent secret aspect may have been one of the driving forces of the selection of whistled speech in various populations. At the same time, however, it often made whistled languages a mysterious subject for various researchers, who mistook them

Fig. 1.3 Views of La Gomera Island where whistled Spanish (locally called *Silbo*) is still practiced. **a** The scattering of dwelling houses in the hills is characteristic of mountainous landscapes where whistled speech is found. **b** A highland valley above the capital St Sebastian. **c** A traditional whistler showing *Silbo* practice in the environmental context of **b** [*Photo a*, *b*, *c* Courtesy of Julien Meyer/Laure Dentel (© Julien Meyer/Laure Dentel 2015. All Rights Reserved)]

for codes that created a substitute for language with its own rules of syntax, vocabulary and the like. In the past, whistled languages have sometimes been compared to Morse code because of their common use for telecommunication. However, Morse code relies on an intermediary, purely symbolic code that refers to the written alphabet. In whistled speech, the relationship between the signifier (the whistled signal) and what is signified (the utterance in normal speech) is not purely symbolic but is based on physical similarity with the vocal signal, combining abridgment and acoustic iconicity (see details in Chap. 7).

It is also important to underline an essential difference between natural whistled forms of languages and a practice employed by linguists studying tonal languages that consists of asking an informant to whistle the pitch of vowels to ease the identification of tonal patterns, even in languages that do not use natural whistled speech. This technique has greatly contributed to the development of modern phonology over the last thirty years because it has helped produce reliable tonal analyses (Moore and Meyer 2014). However, the technique cannot be considered a "whistled language"; it is a linguist's tool, with clearly different objectives. As we will see in Chap. 7, natural whistled speech in tonal languages is more complicated than simple pitch transposition of the vowel nuclei, even in languages carrying a high functional load of information in tones.

1.2 Research Based on Fieldwork Inquiries

1.2.1 The Linguistic Communities Visited by Meyer and Busnel

This work is primarily based on the fieldwork inquiries of Meyer and Busnel. It also draws information from the publications of the linguists, acousticians, anthropologists and musicologists who are studying or who have studied the local language and the way of life in villages where the population uses or has used the traditional practice of speaking with whistles.

Busnel researched whistled languages from the late 1950s to the end of the 1980s. He visited the whistling linguistic communities of Aas (Béarnese geolect of the Occitan language, French Pyrenees), Kusköy (Turkish language, Turkey), La Gomera (Spanish language, Canary Islands), the Mazatec mountains (Mazatec language, Mexico) and the Hmong diaspora in Paris and French Guiana (Hmong language, originally from Southeast Asia). More details on Busnel's fieldwork inquiries are provided in the next chapter.

Meyer began research on this subject in the late 1990s after having discovered this peculiar phenomenon in an article written by Classe in Scientific American (republished in 1998 in the French edition of Scientific American) and continues his investigation today. Discussions between the two authors began in 2002. That year, Meyer had just begun a new formal inquiry on whistled languages for his Ph.D. At that time, the sample of languages represented in the studies of whistled speech remained small in comparison to the approximately 7,000 world languages. Moreover, original recorded material was rarely available, and detailed descriptions were often missing. Consequently, a long-term international inquiry based on fieldwork in different regions appeared to be the only means of finding new sources of whistled speech and collecting enough material to answer essential questions raised by whistled languages. Until today, Meyer's inquiries lasted 30 months in collaboration with the cultural representatives of approximately twenty linguistic

communities around the world. During the first stage of research, a one-year worldwide field survey was organized. Mountainous areas were visited as a priority because they represent the principal biotope where whistled languages have been found in the past. After two other years of laboratory analysis and short additional field trips, a documentation program was launched in Amazonia in collaboration with the Museu Goeldi (Brazil) and the Parc Amazonien de Guyane (French Guiana). During that same period, an informal research team called the "Whistled Language Unit" was also created by Busnel and Meyer together with colleagues who had extensive experience with whistled speech.[1] Finally, in total, Meyer and Busnel collected original ethnographic and linguistic field data in the following communities: Béarnese in Aas, Greek in Antia, Turkish in Kusköy, Akha in northern Thailand and Laos, Hmong in Northern Thailand and French Guiana, Mazatec and Mixtec in Mexico, Spanish in La Gomera (Canary Islands) and Topares (Andalusia), Ewe of Ghana, Siberian Yupik in Alaska (St Lawrence Island), Gavião and Suruí in Rondônia (Brazil), Wayãpi in Brazil and French Guiana and Tamazight in Morocco.

1.2.2 Methodological Concerns

This research required the design of a specific methodology adapted to the special acoustic form of whistled languages, to the reality of their gradual disappearance and to the desire of several speakers to participate in safeguarding this aspect of their oral tradition. The investigation of this phenomenon represents a multidisciplinary challenge. Our methodology has been adapted to the conditions of use of whistled languages, utilizing the techniques and tools of language documentation, phonetics, phonology, psycholinguistics, bioacoustics and sociolinguistics. In each linguistic community, the first step was to identify and survey the most skilled whistlers. Several important questions specific to whistled speech were asked during the study: Where and when do people whistle? What do they whistle and with whom? What is the intelligibility of the most common sentences used in comparison to less common sentences? Can they whistle and understand everything? What are the different techniques and modes of whistling and in which contexts are each used? Do they whistle segments or not? A typology of whistlers' profiles and an evaluation of the state of vitality of the practice were then derived from this information (of the type presented in Chap. 4).

As a representative sample of their skills, the most common sentences used by each whistler were recorded at a short distance. Next, the researchers recorded

[1] Gautheron was a research engineer in the Busnel team in Turkey and the Rialland team in La Gomera. He also works with Meyer studying whistled speech in Atlas. Dr. Dentel worked with Meyer since 2003 in most of his fieldwork. Pucheux is working under the initiative of the association "Lo Siular d'Aas", which seeks to restore the Béarnese whistled speech recorded in 1962 by Busnel.

spontaneous whistled speech, accompanying the speakers during everyday activities that required whistled communications (dual video and audio recordings from the viewpoint of each participant in the dialogue). In complementary elicitation tasks, the speakers were asked to pronounce words and sentences twice in spoken form and twice in whistled forms. All of the different techniques of whistling available in each place were recorded. On that basis, a set of simple sentences was built with the help of linguistic consultants. Depending on the thoroughness of the description, additional sentences were used to complement the description or to perform an intelligibility test in semi-spontaneous and semi-natural conditions (again with dual distance recording). In the latter case, common sentences were mixed with less common sentences, but all were coherent in their natural contexts of use.

The author and his colleagues have benefited from new technological tools that were not available to the researchers of the 1970s, both in terms of documentary research and of technology available to collect and process the data. Today's equipment for collecting data is much more convenient that used 40 years ago, is discrete and robust and is adaptable to difficult climatic conditions. The Internet accelerated the preliminary inquiry to organize fieldwork in collaboration with several researchers around the world. However, it is important to underline that most of the reliable contacts have been found on location. For data analysis, modern data treatment technologies using computer programming and digital signal treatment also permit complete analyses and accelerate data processing.

In each location, research was conducted in accordance with the Declaration of Helsinki. Our work was approved by the ethics committees of our different research groups, and each participant gave written or oral consent. In Brazil, there was no standing ethics committee at the Museu Goeldi, our host institution in Belém. Ethical questions were addressed by an internal investigative committee called a "sindicância". In Brazilian law and practice, the participating indigenous community indicates, either orally or in writing, their informed consent to the proposed research to the local office of the National Indian Foundation (FUNAI), which in turn transmits that consent, in the form of a document, to the central FUNAI office in the national capital. This office issues written research permits. Our research followed these established procedures. Native local authorities authorized our work in all of the visited communities. Permits were obtained from the National Indian Foundation (FUNAI) and the National Research Council (CNPq). In French Guiana, the procedures are similar to those in Brazil. The scientific council of the Parc Amazonien de Guyane and the "Prefecture" of the region authorized the investigation. In St Lawrence Island (Alaska), a land crossing permit was obtained from the Kukulget Inc. and language documentation agreement was signed with the Native village Council of Savoonga.

To ensure accessibility and usability for different scientific purposes and for permanent free consultation by the local speech communities, linguistic documentation procedures were conducted in collaboration with professional linguistic archives. When requested, both native collaborators and university students were trained in linguistic data collection and annotation. Copies of the recordings and

photos obtained in the field were returned to the local collaborators in the desired format (printed, CDs, or DVDs[2]).

Such a policy of research and documentation was elaborated and improved through the years to offer sufficient guarantees to the local communities in order to build a relation of confidence with the speakers. In general, in very traditional communities an 'Agreement for documentation' was signed with the representatives of the native community. It specifies that the researchers would use the recordings exclusively for research (analysis and communication) under the following conditions:

(a) Audio and video copies of the original recordings will be delivered to the local community under the form that they will specify.
(b) A copy of the documented material will be kept by the researchers who will be in charge of preserving it in good conditions and provide free access to it to the Native communities under request of their representative authorities.
(c) These recordings won't be sold.
(d) These recordings won't be given to individuals or organizations which have commercial means without previous authorization from the representatives of the Native community and/or the individual informants (depending of the local rules concerning traditional property rights).

1.3 The Structure of This Monograph

This monograph is organized into nine different chapters, including this introduction. The historical sketch in the next chapter proves that whistled languages have a respectable ancestry, and it shows how researchers have progressively revealed the existence and functioning of this speech mode. Chapter 3 provides a synthetic view of the linguistic and geographical diversity of the phenomenon of whistled languages. We illustrate this diversity by reporting the languages on a world map and by analyzing in detail the relationships between whistled languages and the most typical landscapes in which they are generally found. In the fourth chapter, we present the different social contexts of the use of whistled speech and analyze the dynamic of the attrition of this practice. Whistled speech is arguably one of the most endangered language forms worldwide, and our field methodology had to be adapted to this reality. We analyze the impact of political and social changes on whistled speech and we introduce the initiatives that have been developed in some populations to safeguard or maintain this part of the local language. In the fifth chapter, we describe the different techniques of producing human whistles, and we

[2] See for example the DVDs 'Língua Suruí assobiada' and 'Língua Gavião assobiada' edited with the Museu Goeldi, Brasil (http://www.museu-goeldi.br/linguistica; see section 'Produção Científica/ Multimídia Recentes' of the website).

explain how a whistled articulation is performed to emulate speech. Furthermore, we describe the principal acoustic characteristics of a human whistled speech signal. A comparison with spoken, shouted and sung forms is provided to better characterize the idiosyncrasy of this phenomenon. At this point, we will be able to describe the parameters that explain why whistled languages are efficient telecommunication systems, which is the subject of the sixth chapter. The results of several outdoor experiments will illustrate our explanations. The seventh chapter addresses the phonetics, the phonology and the typology of whistled forms of languages. Several examples of different languages belonging to different whistling strategies are provided. The eighth chapter presents the neurocognitive aspects of whistled speech. For example, the intelligibility of whistled speech is explained in light of human acoustic and linguistic perception. The results of most of the existing perceptual experiments on whistled speech are explored. The ninth chapter is a reflection on the evolutionary perspectives opened by studies on whistled languages. We revisit the music-language relation and some animal whistled communication systems to explore what whistled speech adds to the current debates on language evolution.

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Chapter 2
Historical Sketch

2.1 Whistled Languages and Ancient Texts

Several very ancient texts mention the presence of whistled traditions used for spoken communication. Here, we will cite texts that are possibly related to whistled languages that remain in use today.

For example, two ancient Greek historians described people of North Africa who lived in hills or mountains and apparently spoke using whistle-like sounds. First, Elien (2nd century) explained in the *De Natura Animalium* that the Kinoprosipi people "*didn't have a language but instead used acute whistling*" (1, X, Ch. xxv), and Herodotus (Vth century) mentioned some Ethiopian troglodytes who "*spoke like bats*" in the *Melpomene* (IV: 183). Several works revisiting these early historical sources proposed that these people were most likely related to the Tibbous, a Berber group of South Sudan that lived in rocky mountains surrounding sandy valleys, the type of ecological milieu where whistled speech is useful (Malte-Brun 1826: 11; Basset 1890: 69). Here, the link with a whistled speech practice is not very clear because those authors apparently had never heard of the practice, but these texts are worth mentioning because they underline that whistle-like communications related to speech existed in North Africa a long time ago. The texts also show the surprise of the scholars of those times when encountering such practices. Moreover, we now know that several Afro-Asiatic languages are still whistled in the Omo Valleys of Ethiopia and in the Atlas Mountains in Northern Africa (see Sect. 2.3).

In Asia, several ancient sources mention the practice of *xiao*, a Chinese tradition represented by an ideogram translated as "whistling" by most of the scholars. The earliest examples of *xiao* are found in a Shijing poem (XIth to Vth BC) where the protagonist whistles while singing (Su 2006). The practice of *xiao* was described in various early documents such as Chenggong Sui's (231–273) *Xiaofu* ("Rhapsody of Whistling") or the *Xiaozhi* ("*Principles of Whistling*"). The latter is preserved in a collection of ancient texts called *T'ang Tai Ts'ung-Shu* and has been translated in

J. Meyer, *Whistled Languages*,
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English by Edwards (1957). Its anonymous author was contemporaneous to the Tang Dynasty (he is supposed to have written it in 765). He was later identified in another Chinese ancient text called the *Feng Shih Wen Chien Chi* as Sun Guang, a Supreme Court judge. This "Treatise of Whistling" (Picard 1991) describes the art of whistling in a philosophic and aesthetic way that may sometimes be interpreted as an art of singing with whistles. For instance, Liu (1976) explained that whistling, often mentioned together with singing in this ancient text, was in fact a particular way of chanting verses in China south of the Yangtze River, where the Taoist *belief* dominated at the time. Some scholars go as far as saying that the *xiao* was connected to *kouji* (oral imitation of human and non human voices) after analyzing all the instances of *xiao* in the Han and Six Dynasties literature (e.g., Sawada 1974). The *Xiaozhi* treatise also attracted our attention because it clearly mentions distance communication in mountains in terms of the range reached by whistles (measured in *li,*[1] a Chinese unit of distance). Moreover, the description of the diverse whistling techniques focuses on how to breathe. Accordingly, it is one of the earliest works on phonetics because it explains how to make certain sounds and how to check them when they are made.[2] Finally, it draws a very clear and simple link between ordinary speech and whistling, explaining that the "*air forced outwards from the throat and low in key is termed speech*; *forced outwards from the tongue and high in key is termed xiao* (*whistling*)" (Edwards 1957: 218). According to our inquiry, Southern China is most likely one of the places that has hosted the greatest diversity of whistled speech traditions. Ghizou, Yunnan and, more generally, the geographical area known as the Golden Triangle continue to host numerous languages such as Hmong (often called Miao in China), Yi and Akha (sometimes called Hani in China), which still have a whistled version for both chanting verses and conducting everyday conversations in the distance (see Chaps. 3 and 5).

The oldest undisputable historical proof of the existence of a whistled form of a language dates back to the written testimony of two Franciscan priests who accompanied the French mercenary Jean de Béthencourt when he conquered the Canary Islands in 1402 for the Queen of Spain Isabel the Catholic. In their logbook published in 1609 under the title "*Le Canarien*", Bontier and Le Verrier mention that the islands' inhabitants spoke "*with two lips as if they had no tongue*"[3] (Busnel and Classe 1976: 6; and Fig. 2.1). Thanks to other testimonies, such as the writings

[1] The *li* is a traditional Chinese unit of distance, which has varied considerably over time but now has a standardized length of a half-kilometer (1/3 of a mile). In practice, however, as late as the 1940s, a *li* did not represent a fixed measure. It could be longer or shorter depending on the effort required to cover the distance.

[2] Whistling is dealt with in fifteen chapters, starting from the "First Principles" and ending with the "Conclusion". These chapters list twelve methods of whistling.

[3] Free translation of "parlent de beaulièvres ainsi que fussent sans langue", where "beaulièvres" means "with two lips", from "bel", which is "two" in ancient French (Latin: bis). It is highly possible that this testimony inspired a book by the poet Cyrano de Bergerac that is often recognized as the first book in the literary genre of science fiction*: Histoire Comique des États et Empires de la Lune.*

124 CONQVESTE

grands medecine, & de fruictaiges de diuerses manieres, & y court bonnes riuieres parmy, & y sont les terres bonnes pour tous labourages & bien garnies d'herbages. Le pays est fort & bien peuplé de gens; car il n'a mie esté ainsi foullé comme les autres païs ont esté. Ils sont belles gens & ne viuent que de chair: & est le plus delectable païs que nous ayons trouué és Isles de pardeçà, mais il est bien adesmain, car c'est la plus lointainne isle de terre ferme. Toutefois il n'y a du cap de *Bugeder*, qui est terre ferme des Sarrasins, que cent lieues Françoises, & aussi c'est vne isle ou il y a fort bon air, ne iamais voulentiers on n'y est malade, & les gens y viuent longuement.

Pays bien peuplé.

c. à l'escart,

Salubrité de l'air.

De l'Isle Gomere.

CHAPITRE LXVII.

L'Isle de Gomere est quatorze lieuë pardeçà, qui est tres-forte Isle, en maniere d'vne trefle; & le païs biē-hault & assez plain, mais les baricaues y sōt merueilleusement grandes & parfondes, & est l

DES CANARIES. 125

païs habité de grand peuple qui parle le plus estrange langaige de tous les autres païs de pardeçà; & parlent des baulievres ainsi que si feussent sans langue, & dict on pardeçà que vng grand Prince * pour aucun meffaict les fit la mettre en exil & leur fit tailler leurs langues, & selon la maniere de leur parler on le pourroit croire; le païs est garny de dragonniers & d'autre bois assez, & de bestiail menu, & de moult d'autres choses estranges, qui seroient longues à raconter.

Langue estrange & particuliere.

** Les relatiōs Angloises disent que ce furent les Romains. Voyés annot. art. 28.*

De l'Isle d'Enfer ou Tenerife.

CHAPITRE LXVIII.

L'Isle d'Enfer, qui se dit *Tonerfis*, est en maniere d'vne herche, presque ainsi que la grand Canare, & contient enuiron dix-huict lieuës Françoises de long & dix de large, & en tour le meilleur a vne grand' montagne la plus haute qui soit en toutes les Isles Canariennes, & s'estent la patte de la montagne de tous costez par la plus grand' partie de toute l'Isle; & tout entour sont les baricaues garnis

Tonerfis ou Tenerife.

Montagne haute. Voyés annot. art. 17 & 19.

Fig. 2.1 Relevant chapter of Bontier and Le Verrier book where they mention for the first time in history the whistled practice of the inhabitants of La Gomera Island (reproduced from Busnel and Classe 1976: 7)

of Fray Alonso de Espinosa (1594) and the anthropologists Quedenfeldt (1887) and Verneau (1891), we know that these colonial priests had witnessed a real whistled form of the local Berber language(s) then spoken for long distance communications on the Islands of La Gomera, El Hierro, Tenerife and Gran Canaria by their original inhabitants, commonly called the *Guanche*.[4] There has been a good deal of speculation about the native language(s) of the Canaries, but so little evidence is available that it is difficult to say with confidence whether there had been various dialects of a unique language or different languages. These are now-extinct idioms spoken until the 16th or 17th century. Throughout the 15th century, these islands were conquered by mostly Andalusians and some Castilians, who subdued or suppressed the native Guanche populations. After subsequent settlement by conquerors, these populations were gradually diluted by the settlers, and their culture largely vanished. Given that the idioms became extinct, it would seem that the Guanches who survived the wars and illnesses adapted their whistled technique to their conqueror's language, which they had to learn. When Quedenfeldt and Verneau visited the Canary Islands at the end of the 19th century, the technique had

[4] The term *Guanche* stricto sensu refers exclusively to Tenerife's original inhabitants.

already been adapted to Spanish. Modern-day Canarian culture is Spanish with some Guanche roots, and the technique for whistling the language—now called *El Silbo*, i.e., “The Whistle”—is one of the few remnants of the islands’ ancient language(s), along with a few sentences and individual words recorded by early travelers, supplemented by several toponyms and some words assimilated into the local Spanish. It is on the island of La Gomera that Silbo survived best, and it is there that the first initiative to revitalize a whistled language was launched at the end of the 1990s under the impulse of some traditional whistlers, now called *Maestros de Silbo*, i.e., “Masters of Silbo”. The historical and cultural importance of Silbo explains why the official educational system of the region followed this initiative by including Silbo in the compulsory curriculum of La Gomera’s primary schools, as will be detailed in Chap. 4. The government of the Canary Islands also promoted this oral practice at the international level, and in 2009, Silbo was declared a Masterpiece of the Oral and Intangible Heritage of Humanity by the United Nations Educational, Scientific and Cultural Organization (UNESCO).

In the Americas, the most ancient historical testimony of the presence of a whistled practice dates back to 1755, when a Jesuit historian reported a whistled form of speech among the Ka’aygua people of Paraguay (Lozano 1755): “*they use a proper language difficult to learn*, *because when they speak they rather whistle it*” (cited by Clastres 1972: 113). According to the anthropologist Pierre Clastres, this Ka’aygua population is related to the ancestors of the Aché people, among whom he witnessed whistled dialogues, as pictorially reported in his book “*Chronique des indiens Guayaki*” (Clastres 1972, discussed later in Sect. 4.1).

Finally, there is a large body of colonial literature about whistle systems in Africa, particularly in Western and Central Africa, where musical instruments such as drums, horns and flutes are commonly used to send messages over considerable distances (e.g., Labouret 1923). Early ethnographers were attentive to what enabled the local populations to build networks of correspondence among villages (drums) or distant dialogs between individuals (whistles). Indeed, these methods were commonly used during warfare (drums and whistles) or to communicate the law (drums), and the ethnographers represented the colonial administration. Missionaries also paid attention to these phenomena because the locals utilized them to tell old stories, to sing and to pray. Culturally, the texts that were played and are still sometimes played with the singing or reciting mode of instruments and whistles regularly refer to the traditional cosmogony, which the missionaries had—and sometimes still have—an obscured mission of changing.

2.2 First Linguistic Analyses

It was only at the beginning of the second half of the 20th century that precise linguistic descriptions were produced. In 1948, *Language* published an article by Cowan that was the first comprehensive linguistic study of a whistled form of a language (Cowan 1948). Cowan explains how the Mazatec of the Sierra Mazateca in

Oaxaca communicate at medium and long distances through modulated whistles, with, according to him, the same ease, speed and intelligibility as speech used in the ordinary manner (see Chap. 8 for a full conversation in Mazatec related by Cowan). As noted by Busnel and Classe (1976), the account he gives of the technique employed shows it to be a very simple matter indeed. Mazatec is a tonal language, that is to say, one in which the fundamental frequency of the glottal waveform, which at the auditory level is associated with the sensation of pitch, plays a role no less important for lexical meaning than do vowel and consonant qualities (segments). In the whistled form of Mazatec, which is mostly produced with a lingo-dental technique (Fig. 2.2), the sender extracts from all of the parameters of the speech continuum the prosodic (supra-segmental), i.e., melodic features, of tone and duration, thereby converting the speech signals as we generally know them into a type of tune.

Cowan noted that the same or similar procedures had frequently been observed not only in Central America but also in Africa and in Asia. These techniques are closely related to those of Mazatec whistle speech because they are also based on the tone feature of the various languages involved. As far as we know, the earliest

Fig. 2.2 A Mazatec whistler—lingo-dental technique of whistling (*Photo* © Rolex Awards/Jacques Bélat. All Rights Reserved)

documents to provide reliable explanations of whistled speech in Africa are brief descriptions of the Gurunsi, Banen and Lele, three groups that effectively speak tonal African languages (Eboué 1935; Dugast 1955; Pepper 1956). Whereas the Banen were found to use primarily their fingers to whistle, the Gurunsi primarily used two- or three-hole wooden whistles (see one schematic example on Fig. 2.3). The Lele used either fingers or an antelope-horn whistle with three holes: *In the Mayo-Kebi*, *for example*, *the Lele rarely travel without their* '*tebere*' *hanging around their neck by a lanyard*, *a whistle with three lateral holes* (see Pepper 1956: 9). One example of simple whistled dialog witnessed by Pepper between two Lele speakers was reported together with both a written transcription of the words and a discrete musical annotation of the tones played for each vowel (see Fig. 2.4). As this example shows, at that time, the researchers rarely used recorders, and they transcribed what they heard using the occidental musical annotation, which provided only an approximation of the complex sound reality of such systems. Interestingly, according to Pepper *this domain of musical speech can be expressed in other ways—by whistling in the fingers*, *by blowing in trumpets*, *or by using skin drums* (Pepper 1956: 9).

In Asia, the earliest modern scientific study we know of on whistled speech addresses the tonal Chin Asian language (Stern 1957). The general principle of whistling Chin was also found by Stern as essentially similar to Mazatec and to the

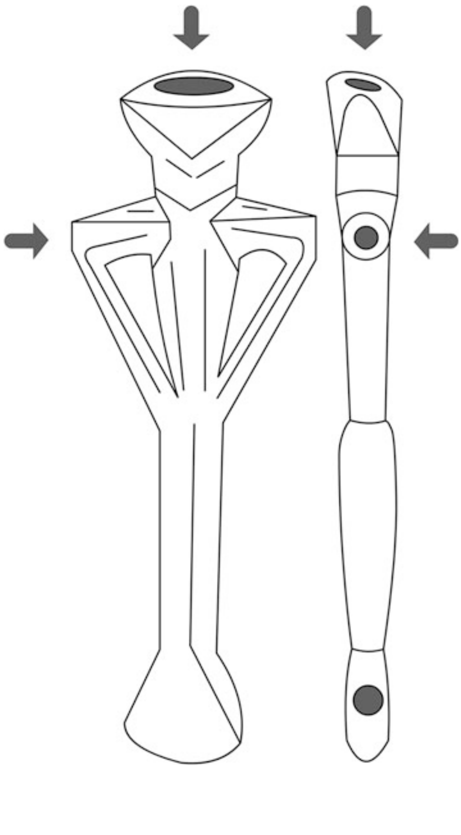

Fig. 2.3 Schematic representation of a Gurunsi wooden whistle. The whistler blows into the upper hole without completely plugging it up (*vertical arrow*). The force of the airflow and the eventual blocking of the two lateral holes (with the fingers, *horizontal arrows*) change the pitch of the whistled signal

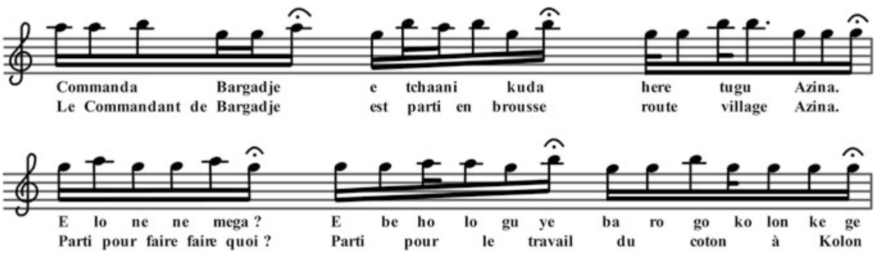

Fig. 2.4 Whistled conversation in Lele language as transcribed by Pepper (reproduced from Pepper 1956: 9). (Translation:—*The commander of Bargadje left to the bush by the road of Azina village.—Left for what*?—*Left for cotton work in Kolon*)

abovementioned African languages. Just like for most tonal African languages, the tone transposition has been also adapted to local Chin musical instruments such as gongs. However, little linguistic detail was provided by Stern about these communication systems.

The studies on Silbo are also important in the history of the description of whistled languages because they are the first to address a non-tonal language, namely, Canarian, which is a dialect of Spanish. The mechanism of Silbo was necessarily completely different from that of whistled Mazatec, Gurunsi, Banen and Lele in that it could not be positively based on prosodic features, at least to a significant degree. In the Spanish non-tonal language, reliance on intonation, stress and quantity in the absence of the articulation of vowels and consonants clearly will not promote ease of communication because these parameters carry only a limited load of functional information for speech intelligibility. A complete description of whistled Spanish was undertaken only in the late 1950s, by the linguist André Classe (1956, 1957), and it was preceded by several attempts that give an idea of the difficulty encountered by early researchers attempting to understand the phenomenon. Of the numerous early articles on Silbo, the most important are Fritsch (1867), Quedenfeldt (1887), Verneau (1891) and Lajard (1891). These articles all describe Silbo as a picturesque and entertaining phenomenon but reveal little about its mechanism, except perhaps in the study of Lajard, who came close to understanding it. Busnel and Classe (1976) accurately note that Quedenfeldt and Verneau wrap the subject in an opaque veil of mystery because they stand by the idea that the pitch of whistling mirrors the pitch of ordinary speech. A description of the mechanism of whistled speech in non-tonal languages will be given in Chap. 7, but it can be stated here that Classe was the first to find that in essence, whistled Spanish consists of replacing the vocal tract resonance of everyday phonation with a whistle, that is to say, a steady or modulated note that is practically a sine wave. Such resonance of the cord tone in the vocal tract defines vowel and consonant qualities that are therefore transposed in whistles (Fig. 2.5). This originates at the front end of the speech tract, not in the larynx, with the factor of articulation remaining as it is in ordinary speech. The document in which Lajard begins to supply a logical explanation of this phenomenon and that might have greatly helped Classe is entitled *Le langage sifflé des Canaries*. Lajard has a very

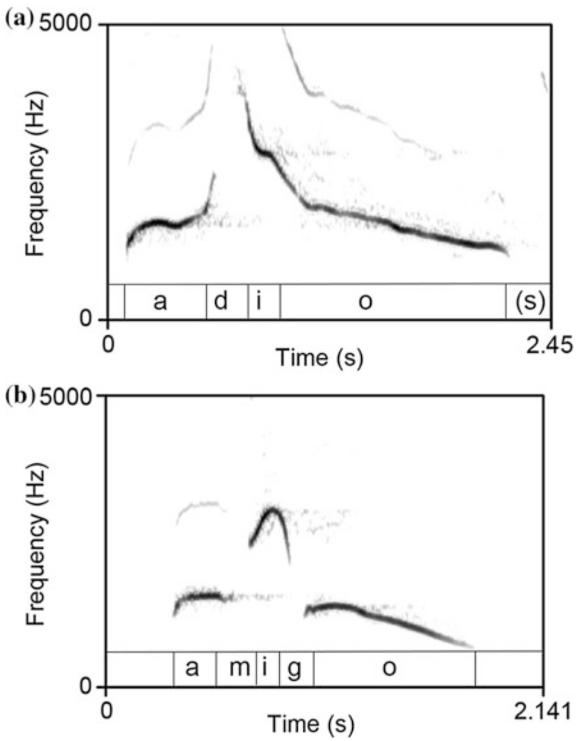

Fig. 2.5 Two whistled Spanish words: **a** /adios/ (meaning: *good bye*); **b** /amigo/(meaning: *friend*). They share the same vowels /a, i, o/ that are rather steady notes but differ in the modulations imprinted by the consonants /d, s/ or /m, g/. One can note also the modulation of the hiatus between vowels /i/ and /o/ of /adios/

clear idea of how the whistle can be used as it is because he realizes that whistled speech is all a matter of articulating vowels and consonant segments, not of the prosodic features of ordinary Spanish, primarily because he tried to learn to whistle Spanish. Unfortunately, his ignorance of linguistics and phonetics prevents him from solving the problem and causes him to give a somewhat misleading account of the process. He seems to think that Silbo is a mixture of whistling and normal speech, apparently not realizing that phonation—an indispensable component of normal speech—is incompatible with simultaneous loud whistling and that the approximation of the vocal ligaments necessary for the production of the cord-tone excludes the possibility of emitting air under enough pressure to produce the penetrating sound indispensable for long-distance communication (Busnel and Classe 1976). Lajard makes another mistake: he thinks that Canarian speech is practically identical with Castilian, which is not the case [as we will see in Chap. 7 and as Classe notes in his first article, which was published in *Archivum Linguisticum* (Classe 1956)]. Before that, Quedenfeldt, to his credit, observes that the only detectable variable in the whistled medium is pitch. To test the idea, he enlists two musicians, who note what they think they hear when Gomeros whistle. The accuracy of the transcription was checked later by Busnel and Classe (1976) by whistling back to other whistlers the musical annotations of the musicians with absolutely no success. The first error of Quedenfeldt is to think that whistled Spanish is entirely a matter of prosodic features

as normally understood in linguistics (although he did not use that terminology). His second error is similar to that made by the anthropologists confronted with whistled speech in African languages because a musician trained along the usual lines in orthodox fashion would automatically refer any pitch he perceives to the nearest note of the familiar chromatic series. As shown in Figs. 2.5 and 2.6b, c and as it will be shown later (Chap. 7), all whistled speech sound realizations are glides interpreted in terms of range, contour and steepness (apart from some rare relatively steady vowel-phonemes). It follows that Quedenfeldt's musicians produce only notations of vowels "normalized" by being forced to fit the Western musical scale. This effect

(a)

(b)

(c)

(d)

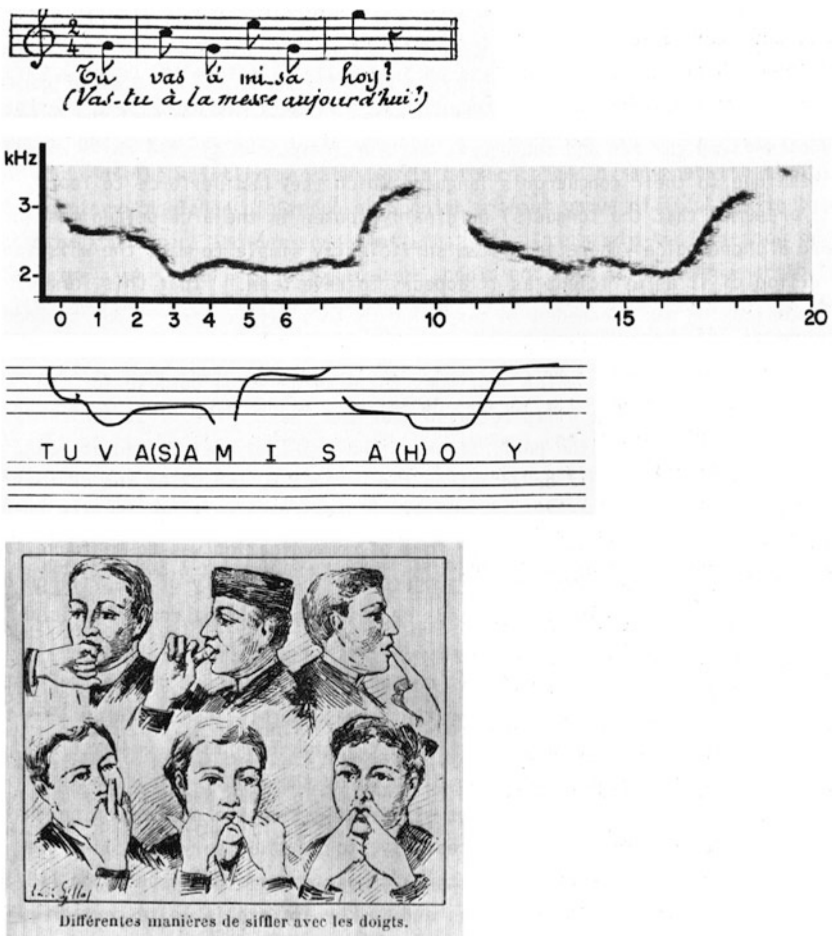

Fig. 2.6 Whistled sentence "Tu vas a misa hoy? (Translation: *Are you going to church today*?). **a** musical annotation obtained by Quedenfelt; **b** Spectrogram; **c** Melodic line of **b** reproduced on a musical scale. **d** Description of whistling techniques observed in La Gomera from: Le Monde illustré, 1893 (reproduced from Busnel and Classe 1976: 9)

would make the interpretation of their signals by whistlers practically impossible. For example, faced with the vowel series [u a a i a oi], even a perspicacious reader will be unable to recognize it as the sentence, i.e., "Tu vas a misa hoi?", stripped of its consonants. Interestingly, Busnel and Classe compare the musicians' version with the genuine article in a figure we reproduce here (Fig. 2.6a, b, c).

The peak of interest for whistled Spanish raised by the articles of Verneau, Quedenfeldt, Frisch and Lajard attracted considerable attention, and their interpretations were reproduced in popular magazines and discussed in some scientific societies, seldom accurately, and often were embellished by journalists and anthropologists. For example, whistled speech was the subject of a notice in *Le Monde Illustré* (Fig. 2.6d). It was also the subject of discussions on the origin of the practice and the origin of language in the *Société d'Anthropologie de Paris*, where Lajard had presented his work (e.g., Bordier 1892). Interestingly, these discussions occurred at a time when the *Société de linguistique de Paris* had informed its members that it would not receive any communication about the origin of language.

One other researcher, René Guy Busnel, a contributor to this chapter, found in whistled speech one of the driving forces of his reflections on human languages and on communication in general, from the early 1950s until the end of his career, and even later. Busnel found a whistled language in France, which appeared inconceivable at that time. Because Busnel was a pioneer in the field of biological acoustics, whistles were already among his research interests, and he found it fascinating that they could be used by humans to transmit messages of linguistic attitude for telecommunication purposes in natural surroundings. He contacted Classe after having read a report of his work in an article of the *Unesco Courier*. When he spoke about whistled speech and played some sounds sent by Classe in a French radio broadcast by ORTF, he received a communication from a listener to the effect that there was what appeared to be a very similar form of communication in the French Pyrenees near the village of Aas, where a local dialect of Occitan (Béarnese) was still largely spoken. The last few users of this whistled version of Béarnese were approached, and their whistling was recorded and duly analyzed (Busnel et al. 1962a, b). Whistled Béarnese was found to function very similarly to Silbo Gomero, but with different vowels and consonants. Then, in March 1964, *The New York Times* published a note entitled "Turkish Town Talks in Whistles", which inspired an expedition financed by the Wenner Gren Foundation, organized by Busnel, with the object of investigating the phenomenon on the spot with a pluridisciplinary team. The expedition showed that the village of Kusköy (literally, "the village of birds") was in a region near the Black Sea where whistled Turkish was still largely practiced by shepherds who called it "kusdili", that is, the "language of birds". Not unexpectedly, it was found to function very similarly to Silbo Gomero, despite the much more complex vocalic system of the Turkish language (see Chap. 7). The results of this inquiry have been published (Busnel 1970, Leroy 1970), and sound films made at Aas and Kusköy were quickly made available to certain research and teaching establishments through the Service du Film de

Recherche Scientifique[5] (SFRS), which Busnel helped launch [see Busnel (1964) on Béarnese, Busnel (1967, 1968) on Turkish and Busnel and Siegfried (Busnel 1990) on whistled speech in general]. In his publications, Busnel approached the topic slightly differently from his predecessors. Inspired by the German school of human ethology (Lorentz and Eibl-Eibesfeldt), he focused on human behavior in relation to the ecological milieu and as an acoustician, he managed to use—for the first time—the most modern technological tools then emerging to record and analyze sounds and images. Thus, one of the first European sonographs was imported from United States to study the whistled language of the Pyrenees. Moreover, in collaboration with hospitals in Paris and Ankara, he captured X-ray images of the vocal tracts of Béarnese and Turkish speakers while they were both speaking and whistling the same words and sentences. The interdisciplinary teams that he gathered were composed of eminent specialists in psychology, acoustics, signal treatment, biology, ethology and linguistics, which greatly furthered understanding of the whistled languages practiced in the Pyrenees, Turkey and the Spanish Canary Islands.

Thus, under the impulse of Busnel, Classe and Cowan, interest in whistled languages reached a second peak around the 1970s. Cowan, after his first study on Mazatec whistling, benefited from the network of information constituted by the missionary linguists of his evangelistic organization, the "Summer Institute of Linguistics",[6] which is still quite active in various autochthonous populations that speak minority languages. He describes the whistled version of the non-tonal Tepehua language of Mexico and mentions all of the languages that his network colleagues note as also being whistled (the list contains thirty languages, some of which have been revealed either to approximate codes or to be actual codes, and there are many parts of the world that he does not mention). Tepehua whistled speech is succinctly described without any sonogram but is clearly described as an articulation-based whistled system (Cowan 1972, 1976). Cowan is also the first to qualify whistled speech as a *style of speech*. Finally, some years later, Classe and Busnel have provided a detailed account of their investigations in a monograph entitled "Whistled languages" (Busnel and Classe 1976), in which they compile a general review of current knowledge in the domain with a description of various aspects of the subject.

In parallel to the work of these three scientists, various linguists have produced ad hoc analyses of whistled languages previously unknown to the scientific

[5] The SFRS has given birth to the Cerimes (Centre de resources et d'information sur les multimedias pour l'enseignement supérieur), and most of the films cited here are freely available for streaming at http://www.cerimes.fr/.

[6] The SIL is an organization that uses linguistics to translate the Christian Bible into minority languages that are primarily oral. Its work is accompanied by a denigration of the local cosmogony and its expression in verbal art, celebrations, and music. The SIL conducts its work despite the clear ethical issues related to the invasive interference of religious activity with traditional beliefs, events, and arts. Nowadays, several countries specify that such interference is forbidden by the law.

community. In Mexico, whistled *Kickapoo* was briefly described in 1954 in a short communication published in the *American Anthropologist* (Ritzenhaler and Peterson 1954). Several interesting points were underlined. For example, the practice was mostly used for courtship messages, principally at night. It seemed to have been derived from a lover's flute tradition, originally used by men to serenade their sweethearts. The technique to produce the whistles consisted of cupping the hands. Air was blown into the cavity between the knuckles of the thumbs placed against the lips vertically. However, it was only in 1971 that some linguistic aspects of this practice were provided in an analysis showing that whistles emulated the pitch of their spoken equivalent (Voorhis 1971). Another important example is whistled *Chepang*, found in Southern Nepal: it was first very simply introduced by Pike (1970) and later precisely described by Caughley (1976) with a new type of analysis based on syllable weight. Interestingly, that different analysis was found necessary because the Chepang language is incipiently tonal, which gives this Tibeto Birman language a special position between the two categories of whistled languages formerly described as pitch-based (for spoken tone emulation) and formant-based (for vowel and consonant emulation) (see more details in Chap. 7). During the same period, a short ethnomusicology study explained that the Hmong people traditionally utilize a leaf vibrating between their lips for courtship messaging and that the tunes they play emulate the linguistic tone of each syllable of the poetic sentences that they compose for this instrument. Because the tonal system of the Hmong language is one of the most complex in the world, the author provides a schematic explanation of it in the booklet that accompanies the recordings (Brunet 1972). Although this explanation is not detailed, the linguistics behind the melody are mentioned. Finally, a double-volume grouping of most of the previous publications related to whistled and drummed systems has been edited by the semiologists Sebeok and Umiker-Sebeok (1976). This publication reached a large audience and contributed to the broad diffusion of articles that had remained unpublished or little promoted. Among them was one paper on whistled Spanish in Mexican region of Tlaxcala; the practice had been noted in the municipality of Juan Cuamatzi (Hasler 1960) and was later heard over much of the southern part of the region, according to Wilken (1979). According to these authors, whistlers of Tlaxcala used teeth, tongue and fingers to whistle, much as in La Gomera. Coberly's (1975) comparative analysis of whistled vowels and consonants in La Gomera and Tlaxcala is not published in the volumes of Sebeok and Umiker-Sebeok (1976), but it is interesting because it found no evidence for the transfer of whistled speech between these two Spanish-speaking whistling cultures. The mystery remains complete about the origin of this practice in Tlaxcala: did it arrive with the Spanish settlers? Or was it transferred to Spanish from local preexisted whistling traditions?

During the same period, a few early works also mention whistled forms of languages spoken in Oceania (Laycock 1977; Townsend 1968; Eilers 1977). These works have only recently been rescued from oblivion in a recent review by Niles (2010), an ethnomusicologist at the Institute of Papua New Guinea Studies who surveyed the presence of whistled speech traditions in a country that preserves one

of the world's highest language diversities. He showed that the work of Nekitel on Wam and Abu? in Papua New Guinea represents the first real attempt to linguistically describe the practice in that region (Nekitel 1992). He also has found recordings of whistled speech in the Telefol and Folopa languages (Grimes 2000).

In 1980, the existence of a whistled version of Greek was revealed by an award-winning 20-min documentary entitled *Antia*, after the name of the only village where it is used, which is located on Eubea Island (or Evia), the second-largest island in Greece (Ioannou 1980). This documentary was followed by three short studies: first, a purely acoustic general interpretation of a few spectrograms; second, a phonetic analysis of Greek whistled vowels showing that the inhabitants of Antia used a whistled articulation of segments in a manner similar to Silbo, Turkish and Béarnese (Xiromeritis and Spyridis 1989, 1994); and third, a sociolinguistic study showing that whistling remained very common among the inhabitants over 40 years of age but was no longer transmitted to the younger generations (Charalambakis 1994).

In parallel, some linguists working in Africa have presented other descriptions of the whistled speech register in tonal languages, such as Bench in Ethiopia (Wedekind 1981), Mooré in Burkina Faso (Junzo 1998), Jóola in Casamance, Senegal (Moreau 1997) and Moba among the Gurma people of Togo and Ghana (Rialland 2005). Moreau's work is a sociolinguistic study of Jóola in which she observes that, additionally, the Baïnuk and the Manjak people of this region also occasionally whistle their respective languages.

Finally, and quite recently, important, detailed descriptions have been published on whistled languages of Central and South America. These descriptions do not appear in the principal reviews dating back to 1976, such as an article on Pirahã (Everett 1985) and a Ph.D. thesis on Chinantec (Foris 2000).

2.3 New Sources of Whistled Languages

Our fieldwork research revealed new examples of whistled speech in several languages, such as Akha (Southeast Asia), Mixtec (Mexico) (Meyer 2005), Siberian Yupik (Alaska) (Meyer 2008) and Tamazight (Moroccan Atlas). Akha was found thanks to the Mountain People Community Development association (MPCD) in Chiang Mai Thailand, and Siberian Yupik was presented for the first time on an Alaskan radio program in 2005. Meyer made contact with the Yupik community in 2006 to invite two speakers to an international forum of first people in France, thus initiating the study of the whistled aspect of that language. New fieldwork was made in summer 2014, this time on site. Mixtec was recorded in a village of the Sierra Mazateca not far from the Mazatec community of Huautla de Jimenez, where only a few sentences were recorded and a full study is yet to be performed. The study of Tamazight is another story. For a long time, historians and Gomero whistlers of the Canary Islands, who inherited Silbo from the Guanche Berber language, suspected the existence of a whistled language in Morocco, the nearest Berber-speaking country with mountainous landscapes similar to those found in the

island of La Gomera. In 2006, Dentel, a member of the "Whistled Language Unit", read the book "Désert" (Le Clezio 1980), in which she found a description of two young shepherds whistling sentences in the Tashelhit Berber language. This information motivated the other members of the unit to intensively research informants who could help the team localize a whistled language in the Atlas. During the summer of 2013, Pucheux travelled to the high Atlas region and met several people able to whistle fluently in Tamazight. Finally, in fall 2014 a field research was launched on this peculiar aspect of this language by Meyer and Gautheron. In Chap. 7, we will discuss some of the first recordings made in Morocco.

In other cases, we were able to confirm whistled speech in languages in which the phenomenon had formerly only been mentioned in dissertations focused on other aspects of the language or in recordings published by ethnomusicologists, including Ari (Fournel 2002), Wayãpi (Beaudet 1997), Gavião and Suruí (Rondônia) (Moore 1984; Guerra 2004) and Bai and Yi (Yunnan) (Xian-Ming 2002; Various Artists 2003) or Spanish in Andalusia (Asencio-Cañadas and Morales-Jiménez 1992). For Ari, additional data were collected by colleagues, and the analysis is in process. For Andalusian Spanish fieldwork of Meyer and Dentel in 2014 gathered sufficient data to show how the whistling technique is original and unique as it uses a clay or wooden whistle (of the acoustic type called *hole tone*, see Chaps. 3, 5 and 7). Moreover, during a five-year stay in the linguistics division of the Museu Goeldi, Brazil, Meyer worked extensively with the whistled versions of Gavião and Wayãpi in the Amazon because those versions are still used in several of the local communities' important daily activities, such as hunting. Suruí whistled speech was also analyzed, but it is no longer used; people only remember how they used to use it. As we will see in Chap. 7, Gavião, a tonal language, provides extensive details on how surface tone is whistled, whereas Wayãpi clearly encodes vowels and consonants in whistles, much as do Silbo, Turkish, Greek and Béarnese.

With the help of Brazilian colleagues, it was also possible to identify other sources in the literature, including those on the Bororó and Karajá, with a rather consistent and detailed linguistic description (Aytai 1986), and briefly in anthropological studies of the Aché (Clastres 1972), the Tuparí (Caspar 1975), the Krahô (Timbira language) (Rodrigues 1999; Meyer 2012) and the Ashéninka (Hvalkof and Veber 2005). When verifying whether these forms still exist, no whistlers were found among the Aché, the Bororó or the Karajá, all of whom have been extensively studied recently by Brazilian linguists whom we met personally. Moreover, only one whistler was found among the Tuparí of Rondônia,[7] near the border between Brazil and Bolivia where the anthropologist Caspar reported the whistled practice as follows:

[7] That whistler was recorded by Moore, coordinator of the Linguistics Division of the Museu Goeldi, Belém, Pará, Brazil.

> The boys, and also adult men exchange at short distances messages by whistling different, rapidly sequenced tone levels. Already in 1948 I observed how young persons communicated with each other by whistling through the community house, which measures about 30 metres, for example before they would go hunting together. In 1955 I did similar observations during the long walk from Rio Branco to the maloca.[8] One evening we set up our nightly camp. Just to inform Öali that I needed something from his luggage, the young Konkwat whistled a message into the forest which he translated for me at my request: "Öali, bring your luggage here!" And indeed, someone whistled an answer back, and immediately thereafter Öali came and brought me the required piece of luggage. On such occasions one whistles at first only the name of the addressee and waits for the answer. Then one sends the message and waits for the confirmation. One whistles just with the lips, without using one's hands or other means. The distance seems generally only short; however, the whistling saves one from having to search or to shout, which is very disliked. (Caspar 1975: 224).

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Chapter 3
The Diversity and Landscape Ecology of Whistled Languages

3.1 Geographic Locations, Language Families

As we have seen in the previous chapter, whistled languages represent a widespread language practice on all inhabited continents. Taken together, the early studies on whistled languages suggest that the ability of a language to spawn a whistled form is not linked to any particular structural characteristic(s) of that language. Instead, the phenomenon appears to be universal, or potentially so. Recent studies, including those resulting from our inquiry, confirm this idea, and the large bibliographical overview of the previous chapter was a first step in documenting that finding. The number of whistled languages has increased considerably, providing more detailed analyses to better grasp the overall diversity of languages involved in whistled speech. According to the quality of the information provided, we identified 42 "attested" languages and 43 more that await confirmation ("reported"). The category "attested" means that a published description or audio recording is available as proof of whistled speech; "reported" means the phenomenon has been mentioned in a peer-reviewed publication without further proof or analysis (Fig. 3.1). The attested languages appear on all inhabited continents and in such widely differing language families as Afro-Asiatic and Niger-Congo in Africa; Algonquian, Eskimo-Aleut and Oto-Manguean in North and Central America; Arawak, Jê and Tupian in South America; Altaic, Indo-European and Sino-Tibetan in Eurasia; and Torricelli, Trans-New-Guinea and Sepik in Oceania. This notable diversity contrasts with former general studies on the subject dating back to 1976 that mention fewer than a dozen attested whistled languages (Busnel and Classe 1976; Sebeok and Umiker-Sebeok 1976). As we began to see in the historical sketch, whistled transpositions of speech are adapted to some essential aspects of language structures, but no structure is known to hinder the development of such a practice. It can be noted that the various tonal languages known to have evolved whistled speech show a large diversity of tonal systems, ranging from the complex contour tone structures of Asia, such as in Hmong, to the much simpler two-level tone systems of the Suruí of

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b Other possibly involved languages, reported only:

North America: Taos
Central America: Amuzgo, Chol, Otomi, Sayula Popoluca, Totonac, Zapotec
South America: Desano, Makurap Sirionó, Timbíra
Africa: Attie, Bafia, Baïnuk, Bape, Birifor, Bobo, Burunsi, Doohwayoo, Gbaya, Gurma, Lobi, Kabye, Kasem, Manjack, Marka, Mofu, Mwana, Nchumburu, Nyabwa, Tshi, Ule, Wobe, Yacouba, Yoruba
Oceania: Aruek, Au, Bauzi, Binumarien, Gadsup, Palai, Tairora (in Papua New Guinea); Punan Busang (in Sarawak, Malaysia)

Fig. 3.1 World map of the attested and reported whistled languages

Rondônia. Similarly, whistled speech stemming from non-tonal languages such as Silbo exists in a very large variety of vocalic and consonantal systems. We will develop these aspects more thoroughly when addressing the phonetic and phonological aspects of whistled languages in Chap. 7.

From the information that we gathered, many other languages are possibly involved in whistling, but additional fieldwork documentation would be necessary to verify that fact. First, the regions already identified as having high whistled language diversity, such as the Amazon, Yunnan, Mexico, Western Africa and Papua New Guinea, are good candidates for further investigation. Moreover, several regions of the world—such as Southeast Africa, Asia beyond Southeast Asia and Southern China, Eastern Europe, the mountainous Western Americas and a large part of Oceania—have never been investigated for this phenomenon.

3.2 Landscape Ecology of Whistled Languages

3.2.1 A Special Relationship Between Landscapes and Whistled Speech

Whistled forms of languages have been found to exist almost exclusively in well-defined types of landscapes. Since the first studies of whistled Mazatec, Spanish,

Béarnese and Turkish, mountainous areas have been the most clearly identified. Our survey not only confirmed the importance of mountainous areas but also highlighted a key association between whistled speech and dense tropical forest environments, which had been mostly overlooked because Cowan, Busnel and Classe never worked on site in that type of ecological milieu. Whistled speech is also often found in regions of the world where mountains and dense forests coexist. This is the case in the Sierra Mazateca in Mexico (Mixtec, Mazatec and Chinantec languages), in the Golden Triangle in Southeast Asia (Bai, Yi, Akha and Hmong) and in the Sepik region of Papua New Guinea (Abuʔ and Wam Arapesh). Finally, there appears to be an association between several African whistled languages and dense savannas [e.g., Gurunsi and Mooré in Burkina Faso (Eboué 1935; Junzo 1998)], but none of the authors of this monograph have worked in such landscapes. All of these aspects are summarized in the map in Fig. 3.2. To better understand what factors drive the special relationship of whistled forms of languages with specific ecological milieu, we will now further examine the local conditions where the populations that engage in whistled speech live.

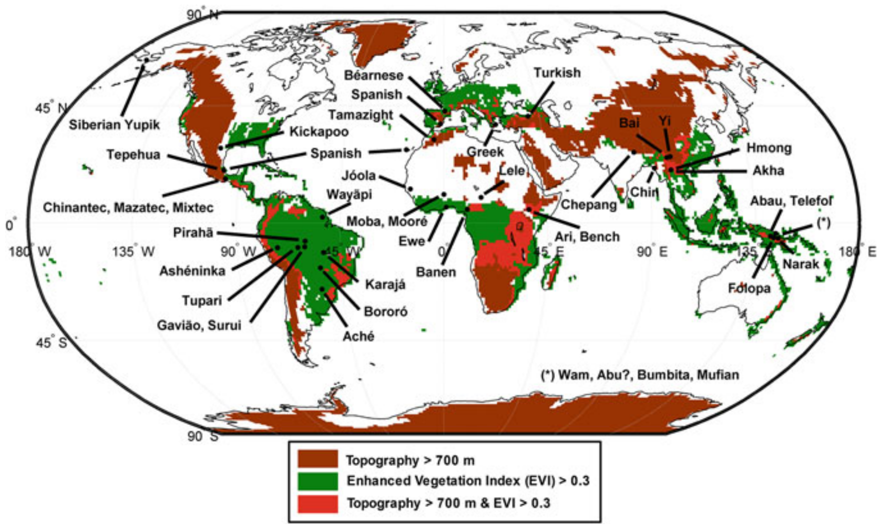

Fig. 3.2 Map of the attested whistled languages in the world including indications of environmental features associated to mountainous and forested areas (topography, vegetation cover) (*Source for topographic data* Atmospheric Infrared Sounder/Aqua level 3 Monthly standards physical retrieval (AIRS + ASMU), Goddard Earth Science Data and Information Services Center (GES DISC). *Source for Vegetation data* MODIS/Terra Monthly Vegetation Indices Global 1*1 degree, NASA NEESPI data and service center)

3.2.2 Mountainous Landscapes

3.2.2.1 The Population of Aas in the French Pyrenees

In the Pyrenees mountain range, which stretches over approximately 500 km, lies the village of Aas (Fig. 3.3), which is located in the Ossau Valley, approximately 120 km from the Atlantic coast. Aas is situated at an altitude of 750 m on the left flank of the Ossau Valley, which terminates at the spa of Eaux-Bonnes. It is known that several villages were settled in the 9th century by large numbers of migrants originating from the town of Beneharum, which was razed in 845 by Normans. The town of Lescar represents the site of the invaders (Busnel and Classe 1976). This area used to be the province of Bearn, near the La Bigore border. The native language spoken by the populations of that region is represented by Pyrenean geolects of the Béarnese variant of Occitan. The village of Aas has long practiced whistled Béarnese, which has now disappeared in its traditional form. Nowadays, only some members of a local association called "Lo Siular d'Aas" managed to

Fig. 3.3 **a** View of some of the highlands and the valleys surrounding Aas, **b** Aas village, **c** A whistler of Aas in the late 50s [*Photos a*, *b* courtesy of Julien Meyer/Laure Dentel (© Julien Meyer/Laure Dentel. All Rights Reserved); *Photo c* courtesy of René-Guy Busnel (© René-Guy Busnel. All Rights Reserved)]

rediscover this traditional practice. In the past, the shepherds were the principal users of this oral tradition. In 1959, at the beginning of the inquiry led by Busnel, 30 out of 150 villagers still whistled for the purpose of human-to-human communication, most of them of approximately 50 years of age. All had been shepherds in their youth. Two women who had been shepherdesses in their childhood could still talk in whistles (Busnel and Classe 1976). Whistled speech was used exclusively under conditions of isolation in the highlands. Shepherds remained in contact with other shepherds and with the village through this practice. Similarly to many high-altitude valleys of the Pyrenees, the Ossau is deeply sunk between steep sides, making communication difficult and effectively isolating populations. In the past, these conditions helped maintain the integrity of social groups and they explain the maintenance of this practice until the 1960s. The inhabitants of the Ossau Valley exhibited specific characteristics that have interested ethnologists. However, before the publication of Busnel et al. (1962), neither linguists nor specialists nor museums and archival curators showed any sign of being aware of the existence of a whistled form of Béarnese, and no mention of one was found in any document previous to Busnel et al.'s field inquiry. An in-depth investigation performed between 1959 and 1974 has shown that the only village in the whole of the French Pyrenees where this phonetic tradition existed was Aas, nor was there, so far as Busnel could discover at this time, any sign of any similar phenomenon in the villages on the Spanish side of the Pyrenees. Even more remarkably, the inhabitants of neighboring hamlets not only did not use or understand the Aas whistled speech, they also seemed to be unaware of its existence, except when they were relatives of natives of Aas.

3.2.2.2 The Turkish Population of Kusköy in the Valleys from the High Plateau to the Black Sea

In the mountainous region of Northeast Turkey, very close to the Black Sea coast and approximately 30 km south of the town of Görele, a whistled form of Turkish is still in use. An investigation of this phenomenon was first conducted in the village of Kusköy ("*The village of birds*", in Turkish) in 1967 by the team of Busnel and then in 2004 by Meyer and Dentel. Busnel and his colleagues found that whistling was used by the entire highlander population, which was dispersed into no less than 35 villages. The total population was thought to be approximately 25,000 in 1970, scattered over an area of approximately 5,000 km^2 (Busnel 1970). The terrain consists of hills that rise to between 800 and 1200 m, their steep sides forming deep and generally narrow valleys (Fig. 3.4). The landscape closely resembles that of the Pyrenees. One of the consequences of the ground configuration is that it makes moving about very difficult. In 2004, the roads to Kusköy were not yet made of asphalt, but some road works were in progress, which attests to the ongoing changes in the region (Meyer 2005). In the 1970s, however, there were no roads adapted to wheel transport, and the winding paths made travelling on foot slow and laborious. Another important feature is the scattering of dwelling houses in the hills, which is the result of the cultivation of crops on terraces forming successions of levels. Halfway up the slope, hamlets and villages

Fig. 3.4 The region of Kusköy (meaning: *the village of birds*). **a** River in springtime fish breeding tanks in a valley near Kusköy, **b** View of the highlands in the region of Görele, **c** Sheep in the main street of Canakci, **d** Some houses of Kusköy village [*Photos* courtesy of Julien Meyer/Laure Dentel (© Julien Meyer/Laure Dentel. All Rights Reserved)]

cling to the flanks of valleys, and rather than the concentration of inhabitants characteristic of plain regions, we find loose groupings of houses sprawling over several km. At Kusköy, for example, there were in 1969 approximately 500 inhabitants distributed in 85 dwellings over 2.5 km (Busnel and Classe 1976). These ecological conditions compelled families to be relatively self-sufficient; there was no commerce to speak of in these villages. The nearest "trading center" was the large village of Canakci, 10 km from Kusköy, where geographical isolation was combined with mountainous topography. Currently, the village is less isolated, and much of its economic activity relies on exchanges with the nearby town of Görele, which stands on the shore of the Black Sea. People still whistle on a daily basis, even if the practice has lost strength. The population has grown to approximately 1,000, and the people are more concentrated in the center of the valley, where a strong river flows. We noted that this river represents an additional strong source of background noise in

springtime, and whistling is therefore useful for people working nearby to ensure that they are well understood (for example, for fish breeding, Fig. 3.4a). The reason that whistled Turkish has been maintained in this valley is most likely because most shepherds continue to spend the summer with their flock in the high plateau above Kusköy, where isolation is still nearly complete. The village also provides an important place for a whistling competition during its yearly spring festival, which tourists and journalists are permitted to film.

3.2.2.3 Spanish Silbo in the Canary Islands

The island of La Gomera is the second smallest of the Canary Islands, lying in the Atlantic off the west coast of North Africa. Its population is scattered over the island in many tiny hamlets and four small towns. It is remarkable for its exceedingly rugged and peculiar topography up to the summit, the Alto de Garajonay, which is approximately 1,500 m high. The central part of the island is surrounded by one of the only two tertiary forests remaining on the planet, which survives thanks to a microclimate of fog trapped by its mountainous surroundings. This forested area is less cliffy than the lowlands, and deep gorges and valleys radiate it (Fig. 1.3). In 1956, when Classe first studied Silbo Gomero, the only means of travel between two points was a number of goat tracks that were in difficult mountain terrain. At this time, two points only 500 meters apart as the crow flies were easily an hour apart in walking time (Busnel and Classe 1976). From the 1970s to the 1990s, communication was greatly improved thanks to roads connecting the main towns, most villages and the touristic points of the island. However, several areas remain quite isolated and can be reached only through large or small dirt tracks. Shepherding and hill cultivations have always played an important role in the island's economy, and whistled speech was very useful in easing communication during such activities. La Gomera remained excluded from mass tourism for a long time compared to other islands such as Gran Canaria and Tenerife, most likely because of the island's lack of infrastructure and its small size. However, tour operators now often include it in their circuits for its two main attractions, namely, the areas declared as Masterpieces of World Heritage by UNESCO: the forests of Garajonay and Silbo. Whistling there was about to disappear at the end of the 1990s because very few traditional whistlers remained. However, in contrast to the other islands, La Gomera has always had a critical mass of whistlers who have maintained good skills. This fact explains why a revitalization project could be launched quite successfully. La Gomera still holds the record for the longest distances at which whistled conversations have been observed. There, it is frequent to speak at more than one kilometer, and Classe has observed communications at approximately 8 km, which is possible only when the climate and the valleys are favorable. Silbo Gomero has another interesting feature: different whistled dialects have been developed in different areas (Busnel and Classe 1976). The people from the region of Chipude, situated on the top of the island, where the climate is often foggy near the forest of Garajonay, use a slower and lower whistled signal than in San

Sebastian, Agulo and Vallehermoso, which are sunk into deep valleys. However, traces of these “dialects” are now difficult to find. The ecological situation of El Hierro, the neighboring and smaller island where Lajard found whistlers at the end of the 19th century (Lajard 1891), is much the same. It is therefore not surprising that some traces of Silbo have recently been found by a Canarian ethnomusicologist who has interviewed elderly shepherds around the island during in-depth field research (Diaz Reyes 2005).

3.2.2.4 Whistled Greek in the Village of Antia, Evia Island, Greece

Antia is a small, remote village located in the southernmost part of Evia (Eubea). The village is in a mountainous area and is sheltered by a valley with a slight slope where a small river flows (Fig. 3.5). This river allows vegetation to grow quite abundantly in the valley, whereas the village’s other surroundings are quite arid. It is the only village on the island where whistled speech has ever been noticed. It is also the only village in which Arvanitika, a dialect of Albanian found in Greece, is not spoken at all; the only language in use is Greek. Therefore, the village differs culturally from the rest of the island. This peculiarity has fueled debates about the origin of the first settlers of this small valley. Three different explanations have been given: the first is that they arrived during the Persian wars (Charalambakis 1994); the second is that the inhabitants of Antia are descendants of prisoners brought from Aïnos (in Thrace), called Canale in 1409, by the Amiral of Venice (Xiromeritis and Spyridis (1989); and the third is offered by the inhabitants, who say that their ancestors developed a secret language because of the arrival of many foreigners (Charalambakis 1994).

In Antia, the primary economic activities remain agriculture and raising livestock. In the past, most inhabitants made their living as shepherds or goat herders, and they used whistled Greek to communicate over the large distances that separated them when they were in the mountains with their animals. They also used whistling in the village to speak from one house to another. They still do so from time to time, even if fewer than four elderly whistlers are true masters of the technique, the others being incapable of whistling due to loss of dentition. However, they still understand everything because they have intensively practiced whistling since they were 5 or 6 years of age (see Chap. 4). According to the 2001 census, the population of the village was 172 inhabitants, but by 2004, when Meyer and Dentel visited the place, the inhabitants reported that there were no more than 50 permanent residents. That remained the case when other linguists and visitors went to Antia in 2009 (Kouneli et al. 2013). The closest large town, Karystos, is approximately 40 km away, and there is still no regular or frequent public transportation to the village. The village remains isolated and distant from education centers and modern work opportunities. The population remained in a dynamic of rural exodus in 2004, either toward nearby towns on Evia Island or toward Athens. Consequently, the younger inhabitants (18–35 years old) were rarely in the village except during school and university holidays. The absence of a “relay generation”

Fig. 3.5 **a** The fertile valley of Antia village. **b** Mr. P. was the best whistler of Antia in 2004, **c** The tavern of Mr. P [*Photos* courtesy of Julien Meyer/Laure Dentel (© Julien Meyer/Laure Dentel. All Rights Reserved)]

in the village resulted in few people learning to whistle. However, some initiatives have been recently launched to try to revitalize this practice (Chap. 4).

3.2.2.5 Whistled Spanish by Shepherds in Topares, Andalusia

As of 2014, at least two shepherds in the Andalusian village of Topares still know how to make a small whistle out of clay that they call a *pito* ("whistle") or a *boca* ("mouth"). In the past, they used these whistles while working both to communicate in whistled Spanish and to give orders to their sheep or their dogs. The village of Topares remained one of the most remote in the Iberian Peninsula, even after the beginning of democracy. Until recently, it had no road access and no electricity or water

distribution, and the local population was principally composed of crop farmers and shepherds. It is now a district of the municipality of Vélez-Blanco, 194 km to the north of Almeria, situated in a fertile altiplano between the Sierra de la Sagra to the north and the Sierra de Maria to the south. The region has always been self-sufficient and quite prosperous because of the fertility of the land. Underground currents of this high plateau region are known as the source of the Guadalquivir River. Moreover, the region has a well-documented history of various populations from prehistoric humans to Iberians, Romanians and Arabs. It is therefore difficult to trace the origin of the technique of whistled speech. The topography around Topares is made of hills culminating at approximately 1,200–1,300 m in altitude, 200 or 300 m higher than the plateau. The houses in the village are distributed on the flank of one of those hills (Fig. 3.6). At the time of the first investigation of this peculiar technique, made by the

Fig. 3.6 **a** A panoramic view of Topares village in Andalusia, **b** The clay whistle called *pito* or *boca*, **c** A former shepherd showing how he uses the whistle [*Photos* courtesy of Julien Meyer/Laure Dentel (© Julien Meyer/Laure Dentel. All Rights Reserved)]

Centro de Documentacion Musical de Andalucia in 1992, the practice was already vestigial, but several shepherds older than 50 in various other villages of the region, such as Cañada de Canepla, Desdre and Puebla de Don Fadrique, were able to explain and demonstrate the technique (Asencio-Cañadas and Morales-Jiménez 1992). The town of Puebla de Don Fadrique, for example, at the north of the region, is situated at the bottom of the summit of the Sierra da Sagra, which culminates at 2,381 m. Everywhere, the shepherds say that they used to bring their flocks from the mountains to the plateau to provide the sheep with different types of food, which guaranteed good health. It was principally in such contexts that they inserted the "boca" into their mouths and articulated Spanish while whistling with this artificial whistling palate. Currently, most of the shepherds come from other regions of Europe, and few of them practice the traditional shepherding of the region. The practice of whistling has nearly been lost, and it only survives in the knowledge of few old whistlers.

3.2.2.6 Siberian Yupik of St. Lawrence Island in the Bering Strait

St. Lawrence Island (Siberian Yupik: Sivuqaq) is located west of mainland Alaska in the Bering Sea, just south of the Bering Strait. The island contains two villages: Savoonga and Gambell. The island is part of Alaska but is closer to Siberia than it is to the Alaskan mainland. St. Lawrence Island is one of the last exposed portions of the land bridge that once joined Asia with North America during the Pleistocene period. It is therefore placed in a geographic location that is key to the history of the Native American populations. Currently, the island is primarily inhabited by Siberian Yupik engaged in hunting, fishing and reindeer herding as along with gathering different types of plants, such as blackberries, blueberries and salmon berries. Reindeer were introduced quite recently after a period of famine that led many families—including all of the Central Yupik people who once lived alongside the Siberian Yupik—to leave. The two villages of St. Lawrence were given title to most of the land on St. Lawrence Island by the Alaska Native Claims Settlement Act in 1971 which give them control to the land use policy. The island remains very isolated, although there are regular visits of ships and daily flight connections to the town of Nome on the North American continent. Episodically, the people of Savoonga and Gambell receive visitors from the other population of Siberian Yupik who reside along the coast of the Chukchi Peninsula in the far northeast of the Russian Federation. The whistled form of Siberian Yupik is the only whistled language known in North America. It began to decline two generations ago with the arrival of electricity, morse communication brought in by young men who had been engaged in the army and shotguns. We observed that some families still use whistling in a number of activities in the village or in their camp sites in summer. The villages are situated in rather flat areas on the shore even if the inland part of this volcanic island is rather mountainous (Fig. 3.7). Moreover, most of these families count ancestors coming from the Yupik villages of the Russian Federation

Fig. 3.7 **a–c** The landscape around Savoonga village in St. Lawrence Island. **d** Whistler showing one of the techniques commonly used in this Arctic region [*Photos a–c* courtesy of Julien Meyer/Laure Dentel (© Julien Meyer/Laure Dentel. All Rights Reserved); *Photo d* © Rolex Awards/Jacques Bélat. All Rights Reserved)]

which are situated in a much more mountainous region. In this arctic region the permafrost and the wind result no tree or even high bush, which favors eye contact in the distance and motivates the development of distance communication. Whistling was traditionally used also for communicating information on boats by hunters looking for seals, walruses and whales because voiced speech would alert these animals of the danger whereas whistling was more discrete. In parallel the Siberian Yupik also developed a rather complex traditional system of optic communication made of coded gestures. Both distance communication systems have declined with changes and modernization of the way of life.

3.2.2.7 Tamazight Berber of the High Atlas

Some populations of the high Atlas still use whistled speech in the Tamazight Berber language. From an historical point of view this region is strategic because it may be related to three other sites where whistled speech exists: Aas in the

Pyrenees, Topares in Andalusia, La Gomera and El Hierro in the Canary Islands. Most of the villages still using whistling in this region are very isolated and with a very traditional way of life. The mountainous topography and the dry vegetation with very few trees favor the occasions to speak in the distance, even on the hilly plateaus (Fig. 3.8). In most of the villages the best whistlers are the shepherds or former shepherds.

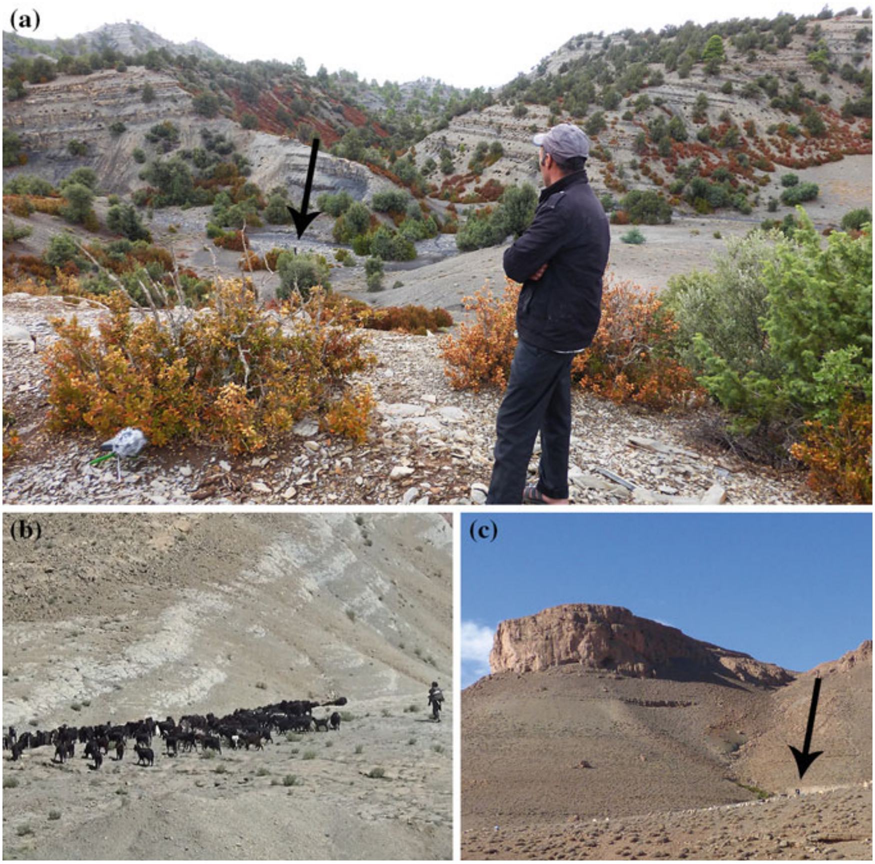

Fig. 3.8 Region of the Moroccan high Atlas where Tamazight is whistled. **a** Whistlers communicating from far, **b** A shepherd with his herd of goats, **c** Typical shelter of semi nomad shepherds [*Photos a–c* courtesy of Julien Meyer (© Julien Meyer. All Rights Reserved)]

3.2.3 *Mountains Covered with Forest*

3.2.3.1 The Chinantec, Mazatec and Mixtec Populations of the Highlands of the Sierra Mazateca

Whistled speech is largely used in several Mazatec, Chinantec and some Mixtec villages of the highlands of the Sierra Mazateca, in the North of the state of Oaxaca, Mexico. This area is mountain country, crossed by more or less narrow valleys that are overall less narrow than those of La Gomera, Aas and Turkey. Moreover, because of the latitude and the tropical climate, these mountains are covered by a very dense forest, which sometimes stretches to the summits (Fig. 3.9). For a long time, the forested mountains have represented an important characteristic of this area because the Mazatec language has no distinct word for either "mountain" or

Fig. 3.9 **a** Landscape in the Sierra Mazateca of the state of Oaxaca in Mexiso, **b** The town of Huautla de Jimenez, **c** The Market of Huautla de Jimenez [*Photos a–c* courtesy of Julien Meyer/Laure Dentel (© Julien Meyer/Laure Dentel. All Rights Reserved)]

"forest". One sentence of our corpora, "*Some live in forests, others in mountains*", highlights this particularity. The closest Mazatec word to summarize both concepts would be translated in Spanish as "*naturaleza*". Until now, these highlands have been mostly preserved from deforestation, in contrast to the lowlands. Many features of the traditional culture linked to the environment have therefore been better preserved in this part of the Sierra. The Mazatec, Mixtec and Chinantec languages are spoken in vast areas where many villages remain isolated in different valleys. This situation explains why each language exists in several dialects. For example, both Mazatec and Chinantec have approximately 14 variants.

The principal center of the Sierra Mazateca is the town of Huautla de Jimenez. It is situated at an elevation of 1,750 m on the slope of a large mountain, and its habitants still occasionally whistle between houses or around town. One of this town's curiosities is the use of whistled speech in the marketplace (Fig. 3.9c). In 1974, Busnel observed two persons conversing by whistling while others were using ordinary speech. In 2003, Meyer observed a shoe seller conversing with people passing by or with other merchants situated above in the market. It is also quite frequent to hear whistled conversations at night or near the bus terminal. The practice is declining all over the region but remains very vigorous in the most remote villages for community work in groups (locally called Faena), for coordinating hill cultivation and for communicating between houses. Among the Mazatec, the usual range of this practice rarely exceeds 700 m. Whistled speech at short and medium distances seems to be the norm. Given the topographic conditions, it is quite possible for whistles to carry at least up to 2,000 m. However, information gathered from the whistlers confirmed that in general, whistling is primarily used for communications of approximately a few hundred m. In two different places, we found people using whistled speech with techniques other than the most common bilabial and linguodental ones. First, near the summit that dominates Huautla de Jimenez, a father and his son showed us that they sometimes speak by pulling their lower lips and breathing in air (Fig. 5.6). This technique provides a clear, strong and acute whistle. In a remote valley of the district of Eloxochitlan de Flores Magon, we met a whistler who whistled with two fingers to reach greater distances (Fig. 5.5a). Such practices remain rare. An important fact that may explain the scarce use of very long-distance whistling is the absence of herds of animals and consequently of isolated shepherds or cowherds who in other parts of the world may well be the inventors (and are undoubtedly the most frequent users) of the system. Additionally, we observed that women hardly whistle at all, whereas in La Gomera, Greece and Turkey, female whistlers were common. Cowan (1948) had already noted that Mazateco women did not whistle at the time he worked there. Children of both sexes do whistle, and it is only the social position of adult women that seems to rule out the practice in that particular culture. In the Chinantec-speaking area, not far south of Huautla de Jimenez, the contexts of the practice of whistled speech are much the same as those among the Mazatec people. In the small town of San Pedro Sochiapam, two consecutive studies focus on documenting and explaining this phenomenon (Foris 2000, Sicoli 2012). Their findings show that whistled Chinantec in Sochiapam is practiced by all of the men, with different levels of expertise that primarily depend on

their ages. The women do not practice whistling, although they may understand it. Whistling is often used over a distance, from one field to another or between houses. It may also be used for fun in situations in which regular speech can be heard. According to the video "Whistles in the mist" (Sicoli 2012; Yetman 2013), whistlers explain that four different whistling styles—corresponding to different techniques—are used to communicate at different distances. For close communication (up to approximately 10 m), the technique of whistling with the tongue against the alveolar ridge is used. Next, bilabial whistling is used for intermediary distances of up to 50 m in open areas. The lingo-dental technique with retroflexed tongue can be heard up to approximately 500 m, depending on the terrain. Finally, whistling with a finger in the mouth is common among the Chinantec whistlers of this town, and it can be heard, depending on the circumstances, more than one km away. Yetman and Sicoli explain that even if whistled speech is still largely known by the inhabitants of Sochiápam, it has quickly lost its vitality in that community. Whistled speech once played a central role in the day-to-day governing of the town, where it was used as a channel to carry information across a difficult landscape to inform local government authorities and committees of the times and places for meetings and to carry news up and down the mountainsides. The long-distance whistled language register has now been mostly replaced by the use of walkie-talkies and the community electronic public address (PA) system.

3.2.3.2 The Foothills of the Himalayas: From Ghizou and Yunnan to the Golden Triangle

Several dozen minorities with different languages live in the mountainous regions of Ghizou, Yunnan, North Thailand, Laos, Vietnam and Burma. This geographical area is even known as one of the important cradles of numerous Asiatic populations that later migrated South. In the region of the Golden Triangle, near the borders between Laos, China and Thailand, the mountains are covered with relatively dense vegetation. When approaching the Himalayas in the direction of Dali and Lijiang, the vegetation becomes scarcer and the valleys deeper. According to our 2004 field inquiry in these areas, several villages still use whistled speech. In the highlands of Yunnan, for example, the Yi people extensively whistle using finger techniques to reach great distances (Various Artists 2003). The Akha and Hmong people who we visited in Northern Thailand and North Laos generally prefer the technique of a leaf vibrating between the lips, which is appreciated both for distance communication in forested mountains and for traditional courtship poetry in the village (Figs. 3.10, 5.8). Leaf whistling can be heard up to approximately 500 m away in semi-forested areas of the type that we investigated (see Chap. 6). It is now useful in field cultivation (rice, sugarcane), during hunting and for speaking discreetly in any circumstances, including those involving resistance against colonizers. Courtship poetry has always been an important aspect of these cultures. In the past, it was not unusual for a young boy to visit the nearby valleys and whistle poems to attract the attention of young girls. If a girl responded, the dialog could continue. The leaf signal guaranteed a

certain level of anonymity and a nice melodic sound that effectively resisted the scattering of the sound in forested areas. At night, the serenades could continue with the same instrument or with Jew's harps, which are also commonly used to emulate speech in this region. Sounds propagated easily through the vegetal walls of the local houses (Fig. 3.10), and the parents were unable to guess who was nearby. Such traditions are also still present in some yearly festivals to promote meetings between young people from different villages. These practices are declining rapidly throughout Southeast Asia.

Fig. 3.10 **a** Whistling leaf technique shown by a Akha woman of North Thaïland, **b** Typical house in a Akha village near the town of Chiang Rai [*Photos a*, *b* courtesy of Julien Meyer/Laure Dentel (© Julien Meyer/Laure Dentel. All Rights Reserved)]

3.2.4 The Dense Amazon Forest

3.2.4.1 Traditional Knowledge and Soundscape in Dense Forests

The Amazon forest is incontestably made of one of the densest vegetation covers on Earth, and it shelters one of the highest biodiversities and one of the greatest language diversities on the planet. The Amazon Basin features a very moderate incline. The rivers flow in very sinuous beds, which increase the separation of populations, which scattered in small groups to cope with the omnipresence of the dense forest cover (Fig. 3.11). Various autochthonous groups still live there in relative isolation,

Fig. 3.11 **a** Wayãpi whistlers using the bilabial whistling technique in French Guiana, **b** Example of typical landscape encountered in a river village of the Amazonian forest, **c** Example of a small temporary shelter made by the Gavião to hide while hunting [*Photos a–c* courtesy of Julien Meyer (© Julien Meyer. All Rights Reserved)]

despite the ever-growing pressures of deforestation, mining and modern life. Very different languages have developed, sáometimes at close quarters. It has therefore always been important for Indians to be able to rapidly identify a person passing nearby in the forest and to be able to converse discreetly with relatives in the midst of vegetation. This skill was vital both in times of harsh rivalries between neighbors and today, with traffic of all sorts crossing these groups' lands. Whistled speech allows human dialogue to go undetected by animals—many of which use similar acoustic signals—and less detectable by other tribes. In such an environment, people and animals permanently scrutinize the soundscape in the absence of easy visual contact. Whistled speech is a major advantage for approaching prey, find or inform relatives and remain discreet. This practice is all the more crucial because hunting and fishing remain among the primary food supply sources in most of the isolated villages. Such activities are still often performed daily. Under these conditions, whistled speech is still very useful to the most traditional and remote populations. It is part of a large panel of acoustic knowledge that they use for navigating and hunting in the forest, among which we additionally observed trunk beating, animal call imitations, simple signaling by means of whistles, high-pitched screaming and even drummed forms of languages [for the drummed Bora language, see Meyer et al. (2012)]. Whistled speech is practiced at distances that are not as considerable as in mountains, simply because the vegetation filters and degrades the sounds. However, as we will see in Chap. 6, whistled speech is much more efficient than normal or shouted voices. All of these special conditions make the Amazon one of the regions with the densest diversity of whistled languages. This diversity is also manifested in terms of language structures because Karajá Bororó, Timbira, Wayãpi, Ashéninka and Aché are known to be non-tonal; Gavião and Suruí are known to be tonal; and there is some doubt about whether other languages that are whistled, such as Tupari or Makurap, are tonal (Moore and Meyer 2014).

3.2.4.2 The Gavião and Suruí People in the Southwestern Amazon

The Gavião and Suruí languages of Rondônia belong to the Mondé family, one of the five families of the Tupi stock, which are found in the state of Rondônia in Western Brazil. The Mondé family is composed of three languages: Suruí, Salamãy (or Mondé) and a language composed of four dialects: Gavião of Rondônia, Zoró, Cinta Larga and Aruá. The Gavião and Suruí languages came into continuous contact with Portuguese at the beginning of the 1940s and at the end of the 1960s, respectively. The current populations consist of, respectively, more than 500 and 1,200 persons living in the indigenous territories of Igarapé Lourdes and Sete de Setembro in Rondônia. All of the members of both linguistic communities speak their native language. The Mondé languages feature distinctive tones and syllable lengths (Moore 1999, 2005). Whistled speech was found among all of the Mondé languages except for Salamãy and Aruá, which are nearly extinct. It consists of the emulation of the pitch and the surface tone of the spoken form. This practice is used primarily for speaking at short or medium distances in the village—even by

children—and for sightless, medium- to long-distance communication in the forest. Between 2009 and 2014, Meyer studied whistled speech among the Gavião and the Suruí of Rondônia. He found only a vestigial practice among the Suruí, most likely because all of their villages are situated at the border of their indigenous territory (see Chap. 4), whereas it is still vigorous in the most remote village of the Gavião, situated in the center of the Igarapé Lourdes Indigenous Territory. Whistled speech in Gavião is extensively used by hunters. Whistled Gavião is also frequent in the villages for many other types of distant communication, such as calling someone, asking someone to bring something, or inviting people to an event (such as bathing, fishing or playing soccer). Because whistling is highly detectable—but discreet towards animals and strangers—in natural ambient noise and effectively resists scattering due to sound propagation, it is also very efficient for signaling an emergency or a danger. In the Gavião language, whistlers continue to practice two categories of techniques of whistled forms: one consists of the classical bilabial whistling and the other consists of various labio-manual whistling techniques that are more powerful over greater distances, especially in the forest. Among the Suruí, however, only labial whistling was found; it is practiced by a few good whistlers. Some of these whistlers are cultural authorities who lived most of their lives before contact with the national society. Therefore, we have no proof that the labio-manual technique that is very popular among the Gavião was ever used before among the Suruí for speaking, even if it is effectively currently used for by the Suruí for signaling. Another interesting point is that whistled singing with bilabial whistling was also found in two Suruí villages, whereas it was found to be performed with a bamboo flute or a leaf among the Gavião (see Chaps. 5 and 9).

3.2.4.3 The Wayãpi People of the Oiapoque River (French Guiana)

Wayãpi is a Tupi Guarani language spoken on both sides of the border between Brazil and French Guiana. Whistled Wayãpi was found to be used under the same circumstances as whistled Gavião but mostly performed with the bilabial technique both in the village and in the forest (Fig. 3.11a). Whistled singing is also performed with a flute made out of a deer bone (Beaudet 1997). Only preliminary inquiries and recordings have been made so far on the spot but some linguistic commentaries will be given in Chap. 7.

3.3 Conclusion

Whistled forms of languages are distributed worldwide and survive only in some of the most remote villages on the planet. They are not limited to a given continent, language family or language structure, but they have been detected by researchers and travelers only sporadically because they can be taken for non-linguistic phenomena

such as signaling. One striking aspect of their worldwide distribution is that they are almost exclusively found in association with certain types of habitats.

All of the ecological zones that we explored to find whistled speech create a demand for long-distance communication because their dense vegetation and rough topography isolate individuals and constrain spoken communication. Mountainous topography necessitates speaking at a distance by increasing visual range, favoring scattered settlements and hindering easy travel between any two points, and by creating large open spaces favorable to signal transmission. For example, valleys create real wave guides, whereas altitude differences contribute to good signal propagation. Conversely, the vegetation in dense tropical forests and savannas restricts visual contact and limits the propagation of sound. For example, in the Amazon rainforest of Rondônia, where the Suruí and Gavião use whistled speech, people lose sight of one another after only 20 m of separation, while normal speech is absorbed and dispersed by vegetation, quickly losing intelligibility. These ecological features seem to represent at least one of the necessary conditions of the existence of whistled speech communication systems, if not their invention through necessity. Another parameter emerging from our descriptions is that whatever the multiple contexts in which whistled speech is used in each place, the people who engage in whistled speech principally make their living as shepherds or goat herders, hill cultivators or game hunters. In each place, the most popular whistling technique is always correlated with such dominant food-supplying activities, which are themselves partially dictated by the landscape.

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Chapter 4
Whistled Speech and Language Ecology

This chapter describes the most common contexts of the use of whistled speech along with the dynamics that explain the strong decline of this practice. We show that the special association of whistled speech with certain traditional outdoor activities makes it very sensitive to behavioral changes due to the modernization of the countryside to the point that we diagnose the phenomenon as universally endangered. Here, we compare the impacts of political and social changes on whistled speech to those generally found by linguists on spoken language in the frame of *language ecology*, which is a domain of research that addresses the dynamics of interactions between languages and their sociopolitical contexts. At the individual level, we identified the same categories of whistlers' competences worldwide, which are quite similar to the profiles of speaker of languages that are undergoing a strong vitality loss, as documented in the work of Dorian (1981) and Grinevald (2003). To illustrate the general tendencies of attrition at the population level, we describe case studies where whistled speech has died (Aas in France), is close to death (Antia in Greece) or is under serious threat (the Gavião population in Brazil). Finally, we explore the different initiatives that have been developed to safeguard or maintain this language register, namely, documentation, archiving, revitalization and even revival.

4.1 Principal Contexts of Use

As we have seen in the previous chapter, whistled speech exists in low-density and very remote linguistic communities, facilitating the organization of everyday life when ordinary speech is inadequate. The ethnographic survey undertaken during the preliminary steps of our fieldwork emphasized how both the origin and survival of whistled languages are linked to traditional outdoor activities. The traditional organization of the local societies described in Chap. 3 depends on food-supply activities that are greatly eased by whistled speech communications. In summary, whistled speech was particularly found in association with the coordination of group activities such as hunting, gathering, harvesting or caring for cattle.

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Moreover, because whistled speech is highly detectable through ambient noise, it is very efficient for signaling an emergency or other danger. In mountains, it was always found to be connected with pastoral and agricultural activities, where it serves to hail a person, to give an order, to transmit news or to draw attention to an unusual situation. Shepherds use it extensively because they escort the flock in high mountain pastures and need to exchange information with their distant village or with other shepherds. For example, in mountains near the Black Sea (where Turkish is spoken), shepherds have been observed to whistle the entire day, giving news, conversing about the weather, joking and even reciting newspaper headlines. Conversely, during hunting, whistling allows human dialogue to go undetected by animals, a major advantage for approaching prey. For this reason, it is widely found in dense rainforest environments such as the Amazon and the Papuan jungle. Whistled speech was also sometimes found in very noisy environments, such as the marketplace in the Mazatec town of Huautla de Jimenez in Mexico or on the shores of a river in the valleys near the Turkish village of Kusköy (as seen in Chap. 3). Even the sung mode of whistled speech found in various Asian and American cultures plays an important role in the constitution of new families because it is linked to love poetry and courtship before marriage (Busnel et al. 1989; Meyer 2007). Finally, whistling has an intrinsic secret side that has always been exploited in the presence of outsiders. Both at close and at long range, whistlers exploit the fact that whistled speech requires an additional training phase to exchange information discreetly. One pictorial report of close, secret communication has been made by the anthropologist Clastres (1972), who spoke the Aché language reasonably well and had shared the daily life of some of his informants during long periods. He related his first experience of whistled speech as follows:

> One afternoon, I was listening absentmindedly to the conversation that he [his informant Jyvukugi] was having with his wife. After a while, I realized that I couldn't understand anymore what they were saying and that, instead of speaking, they were whistling! […] All this was naturally indecipherable to me. Yet, it was normal Guayaki, the one I understood partly: but reduced to its consonantal structure that could be whistled and to its vowels transposed to air emission. In fact, the language that we can whisper but here reduced to its most simple perceptible expression. Indeed, the poverty of the sounds didn't seem to alter the vivacity of the conversation between Jyvukugi and his wife. […] I am nearly sure that they were whistling this day to prevent me to understand what they had to say to each other, and it was a full success (Clastres 1972: 112–113).

Interestingly, as an astute observer, he noticed that vowels and consonants were articulated to transpose normal speech into whistles in this language and that Aché people still achieved good intercomprehension despite the odd manner in which they had to communicate with whistles. In the Amazon, such early mentions of whistled speech are rare, despite the fact that it is one of the few places in the world where whistling survives quite well in various communities, as recently shown by our field inquiries (Meyer 2012, and see Chaps. 2 and 3). In all of the visited communities, there are numerous historical anecdotes about the use of whistled speech for secrecy, sometimes in reaction to dramatic events such as the pressure of a dominant or invading society. For example, in the mountains of the French

Pyrenees, whistled talk was used in the local Béarnese dialect of the Occitan language to avoid taxes during the Second World War because it permitted shepherds with a wide view of the valley to warn the villagers when an official was arriving (Arripe 1985). On La Gomera Island, Guanche Berbers used whistled speech to coordinate resistance to invasion by French and Spanish colonizers (Busnel and Classe 1976). Later, whistled Spanish was used during Franco's dictatorship to avoid being understood by the Guardia Civil (i.e., the Spanish federal police). The same type of reports were made by locals in the Atlas, where whistled Tamazight was used by the Berbers in resistance against the French armed forces, who themselves used optical signaling for long-distance communication. In Papua New Guinea, Wam whistlers were even recruited by the Australian army during the Second World War to successfully evade Japanese radio spying, translating military messages into their language and then passing them through the radio using whistles (Nekitel 1992).

4.2 Vitality Around the World and the Dynamics of Attrition

The ethnographic survey also highlighted how the progressive disappearance of traditional activities in rural communities leads to the declining vitality of whistled languages. Whistled speech is now close to extinction in most of the local communities visited during the fieldwork inquiries. More precisely, it is at risk of disappearing within the next two generations almost everywhere where it survives. In other places, the practice is already gone. For example, we did not find any trace of whistled speech among the Tepehua of Huehuetla in Mexico or the Béarnese of Aas in France, two populations where it has been studied in the past.

4.2.1 The Same Dynamic of Attrition Everywhere

All over the world, we observed the same dynamic of attrition due to progressive acculturation and the social and political depreciation of traditional ways of life in the countryside. The main steps to decrease local interest in a traditional whistled speech register are as follows. First, modern means of communication and transportation increase exchanges with the nearby trade centers, i.e., towns and cities, where the dominant and now globalized model of industrial society increases in power every day. Local communities become less isolated and progressively adopt some aspects of this new model. Families considerably reduce the efforts associated with their daily activities by using motorized vehicles and roads for transportation, telephones and radio receivers for telecommunication and guns and ammunitions for hunting. Therefore, interest in a natural means of communication is decreased

by reorganizing outdoor activities. Moreover, changes to inhabitants' consumption habits are making them less self-sufficient and less dependent on traditional activities. As a result, vital traditional activities that maintained whistled speech are gradually abandoned or completely reshaped to render them useful in the context of modernity.

Moreover, the great isolation of the villages, which are far from educational and employment centers, has resulted in rural exodus, which contributes to the aging of local populations. A growing proportion of young adults leave to study in town, sometimes for most of the year. The relay generation that could learn and maintain whistled speech is being reduced because a portion of it returns to the village only for weekends or holidays. Sometimes schools close in remote villages because of a lack of a sufficient number of pupils, for example, in Antia (Greece). Consequently, whole families move to areas with a denser population, where they imagine they can secure a better future for their children. For example, the small islands of La Gomera (Canary Islands), Eubea (Greece) and St. Lawrence (Alaska) do not offer the possibilities of the large nearby towns, such as Santa Cruz de Tenerife, Athens or Anchorage, respectively. Consequently, numerous inhabitants move to these cities permanently. Similarly, to profit from modernity and to remain in contact with relatives living in town, more than half of the Gavião population moved to villages directly connected to the town of Ji-Parana by a road (see Sect. 4.2.3.2). In some places, modernization of the countryside has accelerated environmental degradation, which in turn has accelerated rural exodus. For example, the very rapid deforestation of the Amazon jungle in the Brazilian region of Rondônia has led the Suruí to move all of their villages at the border of the land delimited as a federally protected indigenous territory so that they can limit invasions by other Brazilians immigrating from the south. Such villages are in regular contact with the town of Cacoal and increasingly, young people ultimately settle there. The rural exodus often completely interrupts intergenerational transmission because the essential purpose of whistled language communication is lost in urban environments.

Therefore, modernization of the countryside, together with its consequences on the local society, is the principal factor impacting the vitality of the practice of whistled languages. Traditional contexts of whistled language acquisition are becoming rare. This phenomenon is underlined by the fact that even whistled speech in a dominant language, such as Greek, Spanish or Turkish, is rapidly coming under threat.

4.2.2 Language Shift and Whistled Languages

The majority of whistled forms of languages pertain to local minority cultures, and most of the changes affecting the vitality of spoken or sung forms of languages (see Grenoble and Lindsay 1998; Nettle and Romaine 2000; Moore 2007) have a deep impact on whistling. One of the dominant forces in linguistic ecology is language shift, which primarily affects minority languages. Therefore, important factors to

consider when analyzing vitality loss in most whistled forms of languages are those related to the status of native languages in each country and the associated politics of the valorization or depreciation of minority cultures. Language shift occurs when a population of speakers adopts a new language at the expense of their mother tongue, generally over the course of a few generations, and it is the most significant driver of language extinction (Loh and Harmon 2014). Different general tendencies in the dynamics of language shift have been found as a function of the history of each world region:

> Language shift is driven by a number of social, political and economic factors including migration, urbanization, national unification, colonization, and the globalization of trade and communications. Governments in many developed and developing countries actively promote a single national language at the expense of other, usually minority, languages for political reasons. This has been the case with Mandarin in China, French in France and Amharic in Ethiopia for example. Migration, urbanization and political nationalization have been the primary drivers in Africa, Asia and Europe, where language shift has tended to occur between languages within the region. In the Americas and the Pacific, especially Australia, the primary driver has also been migration, but the migrants, mainly European, vastly outnumbered the indigenous populations, and so it was the migrants' languages, primarily English, Spanish and Portuguese, that became politically and economically dominant. It is in these regions where indigenous languages are most highly threatened (Loh and Harmon 2014: 45).

These continent-specific tendencies closely match the particular situations that we observed in the populations using whistled speech. Some small minority groups have been completely disorganized by the shock of colonization. For instance, the Aché people of Paraguay have lost their nomadic way of life. In other places, national unification policies deliberately ban the minority language, particularly at school and in local administrations, in favor of the dominant language. This was, for example, the case in Aas, where French was promoted over Béarnese. This situation means that the local language, culture and traditional way of life were depreciated both outside and inside the linguistic community, which had negative consequences for whistling because people were ashamed to speak their native language and even more ashamed to whistle it. In Aas, several testimonies show that whistled speech was discontinued partly because the remaining whistlers of the village refrained from whistling in front of the inhabitants of nearby villages and towns so as not to be victims of incredulity or mockery (Arripe 1985). Language shift accelerates the effects of modernization on whistling vitality and of the younger generation letting the practice die out.

In remote indigenous communities of Oceania, Africa, Asia and the Americas, the local religion has sometimes changed under the pressure of missionaries who spread the attitude of denigrating a part of the traditional oral repertoire, such as traditional singing and dancing or pre-hunting rituals. Finally, the oral patrimony is transmitted only partially because festivals and storytelling are no longer practiced. This change greatly affects the practice of courtship whistling and the singing mode of whistled speech, which often find inspiration in traditional songs and myths.

However, in the context of language shift, an essential difference exists between whistled and ordinary speech when the traditional way of life is well maintained

because the associated whistled form can survive despite the language shift. For example, whistled speech was adapted to the dominant language on La Gomera Island with a transfer from Guanche Berber to Spanish (see Chap. 2). This process may have also occurred with whistled Spanish in Tlaxcala (Mexico). However, it appears that there is a barrier to this type of transfer linked to the tonal/non-tonal structure of the languages in contact, or more precisely to the difference between pitch-based and formant-based strategies of whistled emulation. This phenomenon is interesting enough to deserve more explanation: if both languages belong to the same typological category, the transfer happens easily; but if one is tonal and the other is not tonal, the transfer has never been observed, most likely because of a difficult-to-cross conceptual gap between pitch and segmental emulation strategies. In La Gomera, Guanche Berber and Spanish were both non-tonal. In Tlaxcala, most of the indigenous local languages are, similarly to Spanish, non-tonal, which explains why inter-language transfer may have happened, unless it was Gomero or Andalusians who brought whistling to Mexico. In contrast, the Mazatec people, who are now largely bilingual in Spanish and Mazatec, never succeeded in transferring the pitch-whistling strategy of Mazatec to the formant-whistling strategy necessary to properly whistle Spanish. We even observed that some young whistlers claimed they could whistle in Spanish but in reality only whistled the pitch melody of Spanish, never achieving a good intelligibility for messages more elaborate than names or very simple set phrases.

4.2.3 Typology of Whistlers

In each linguistic community, the first step in our documentation methodology was to identify and inventory the limited number of skilled whistlers. A tentative typology of whistlers' profiles and an evaluation of the state of the vitality of the practice in different places were developed on this basis (e.g., Meyer 2010). Here, we will refine this approach by highlighting more precisely the similarities and differences with typical speakers' profiles observed by linguists in languages subject to intense decline.

4.2.3.1 Whistlers' Profiles

Whistlers themselves generally use qualifications to characterize distinctions of competence, such as "very good whistler", "good whistler", "he/she only understands", "he/she can't whistle anymore". This statement is particularly true where the practice of whistling is maintained only by a part of the community, and such criteria are more common when the practice is endangered. The increasing rarity of the use of whistling as a practical daily means of communication reinforces differences between those who maintain traditional outdoor activities and those who have adopted a modernized way of life.

As we will see in the list below, we have developed a terminology that is partly inspired by one of the whistlers. We also found that the terminology developed by linguists describing endangered languages was still relevant when only whistling was losing vitality, that is, when only part of the language was endangered. Therefore, in parallel with the denominations of “fluent speakers”, “semi-speakers” and “terminal speakers”, which are commonly used by linguists to characterize speakers’ profiles in the standard spoken form (e.g., Dorian 1981; Grinevald 2003), we used “fluent whistlers”, “semi-whistlers” and “terminal whistlers”. When necessary, we added criteria related to the time when the individuals either learned to whistle or lost the whistling practice. For example, the term “traditional whistler” indicates a person who acquired the whistled aspect of the language early in his life in the traditional contexts of use, just after acquiring speech. A “late whistler” is someone who learned to speak using whistled language several years after primary language acquisition. For a “former whistler”, the practice was discontinued in the course of his life due to aging or to a change in his way of life.

‘Fluent whistlers’: these are the whistlers with whom field linguists would like to work because they have mastered the production and perception of whistling up to the point that they can manage any sentence you may imagine, even sentences that he/she would use only rarely. They also possess strong powers of transmission to reach the greatest distances of communication useful in everyday life. The whistlers themselves qualify some as ‘very good’ because they have additional whistling fluency beyond ‘good whistlers’ that provides a better clarity of their sentences for the whole population. Fluent whistlers are often traditional whistlers.

‘Semi-whistlers’: these individuals have limited competences either (i) in production or (ii) in perception, or (iii) in both production and perception. All three cases happen at different stages of apprenticeship. The first case (i) is also quite common among women, children and older people because they are less likely to use whistling as a daily working tool. However, the perceptual abilities of this category of whistlers are often excellent because they need to understand the whistled speech produced by their relatives. The limitation in production also sometimes affects older speakers for physiological reasons (loss of strength of blowing or loss of dentition) or even for other cultural reasons (for example, elderly Mazatec speakers no longer whistle because whistling is considered to be a young person’s practice). The case of semi-whistlers in both perception and production (iii) applies to people not using whistled speech on a regular basis (because they forgot it after many years or because they never learned more). These semi-whistlers easily whistle in commonly used sentences but have difficulty understanding or producing longer sentences. They also often have difficulty evaluating their skills.

‘Terminal whistlers’: these whistlers know set phrases understood by nearly everyone, sometimes called ‘canonical locutions’, and the whistlers who only use these phrases can be called ‘canonical whistlers’. When the population is mostly composed of canonical whistlers, the whistled language is nearly dead, as only a few canonical whistled locutions survive. If the situation persists, these locutions are used as codes, with only a historical link to the lost meaning of the sentence.

'Rememberers': this category corresponds to persons who at one time in their life had a better knowledge of whistled speech. This situation can be sometimes reverted.

'Ghost-whistlers': these are fluent or near-fluent whistlers who hide their ability from outside researchers for various reasons, including shyness in contexts of deprecation of the minority language or of the traditional way of life.

'Last whistlers': Just like for speakers of a nearly dead language, identifying whistlers is a long process, and it is only after inquiry and verification in the whole population that last whistlers can be identified.

These categories are important to identify with whom to work and how to adapt methods of linguistic elicitation and analysis. However, consistent with what Grinevald (2003) states about typologies of speakers, our typology is not static. For example, semi-whistlers can become fluent whistlers and vice versa. These aspects are important in documentation and revitalization projects. The level of competence in whistled speech depends on a large number of factors linked to each whistler's personal history. Such typologies are also useful for understanding the dynamics of the process of attrition by looking for convergences in the behavior of all whistlers.

4.2.3.2 A Case Study with All Profiles in the Same Culture: The Gavião of Rondônia

We have chosen to describe the situation observed in the field among the Gavião, where traditional whistlers as well as former, late, good, very good and semi-whistlers are present. The Gavião example is very complete, with a short but harsh history of contact with the national community. Their current situation illustrates how "*history and social forces remove the contexts in which the language was always used*" (Moore 2007: 32) with a strong impact on traditional knowledge and thus, on whistled speech. An important aspect of this history concerns the simultaneous destruction of the ecological milieu and of the most traditional part of the Gavião's oral patrimony. The Gavião case also illustrates the possible loss of vitality of the whistled form when the spoken form is not yet in great danger, showing that whistled speech generally dies before ordinary speech.

The Gavião (self denomination "ikõléèy"), who came into contact with the national community during the 1940s, have a population of more approximately 500 persons in the Indigenous Territory of Igarapé Lourdes in the Brazilian state of Rondônia. All Gavião speak their native language. Since 1975, their linguistic data have been collected by Moore and analyzed in his dissertation (Moore 1984) and in more recent works. Since 1977, Moore has collected lists of words in whistled and spoken form in face-to-face recording and has observed whistled behavior in traditional activities (mostly hunting but also practical calling in the village). Despite the fact that the Gavião language is still spoken fluently by all generations, their traditional way of life has undergone several drastic changes, especially because of the construction of BR-364, the road crossing Rondônia, and consecutive invasions and destruction of the forest by farmers and illegal log dealers. The invasion of the land by missionaries of invasive religions has also weakened the vitality of traditional

knowledge (the missionaries of the evangelistic *New Tribes Mission* remain illegally settled in one village situated in a deforested area). In 2010, the limit of deforestation was the proper limit of the Indigenous Territory, especially on its western side, whereas the eastern side, situated at the border between Rondônia and Mato Grosso, has been in the process of being illegally deforested in recent years. Over the last 25 years, nearly half of the Gavião inhabitants of this federally protected area have moved from the remote villages where they had lived since the moment of contact to new settlements situated at the southwestern border of the indigenous territory. Most of the new villages are therefore in areas formerly deforested by illegal invaders who have been ejected from the land by the federal police and the Fundação Nacional do Índio (National Indian Foundation, or FUNAI). According to the Gavião collaborators, one of the principal reasons for the resettling was for the community to benefit from the facilities offered by the dominant national culture, namely, commerce, the food supply, education and healthcare. The great disparity of practice of whistled speech among the Gavião reflects this history and its consequences on Gavião cultural habits. In the villages situated on the border of the forest, good whistlers are rare, and most of them are traditional whistlers over the age of 50. They rarely practice whistling because few of them still depend on hunting. Moreover, very rarely do young boys still accompany the remaining hunters in the forests. In the village, the young generation still uses whistling to call people to play football but for very few other purposes. Accordingly, whistling already has a canonical or formulaic aspect for most speakers of these villages. Whistled speech is much more present in the villages surrounded by the dense forest. Boys and girls of the youngest generations use it to call each other and to play together. The oldest and the intermediate generations also use it, both in the village and in the forest, even if it is less frequent than in the 1970s. Some informants showed that they also still know the sung mode of whistling with a leaf or with a flute (for a description of the flute practice, see Chap. 5 or Meyer and Moore 2013). To summarize, in each place, the competences and the attitudes of the whistlers vary first as a function of age. The generations above 40 years old all lived most of their life traditionally and therefore all practiced whistled speech intensively during their youth. Next, the whistlers' competences and attitudes vary as a function of the village's ecological situation, of each family's food-supply policy (maintaining or not maintaining traditional food supplies, such as hunting) and of each family's transmission policy of traditional uses.

Accordingly, the Gavião culture provides a good observatory for the evolution of the whistled language phenomenon because many different steps of vitality loss are simultaneously present in different villages. Because the ordinary spoken form is still very healthy and is learned as the mother tongue, there is still very little impact of language shift of the spoken form on whistled speech vitality loss, except among the children of the families settled in the town of Ji-Parana. However, the vitality of the whistled speech practice and its distribution in the population is emblematic of the situation of all other traditional aspects of the Gavião culture. Therefore, the level of vitality of the whistled practice may be taken as a warning indicator of the possible fate of the entire language if the national dominant language continues to pervade the Gavião way of life.

4.2.4 Two Examples of Strong Decline: Greek and Béarnais

We have seen that the degradation of whistled speech is multi-factorial and results from substantial changes in a local society. We will now observe two other examples illustrating this process. The cases of the Aas village in the Pyrenees and of the village of Antia in Greece show that without any strong initiatives to safeguard and revitalize the whistled language, it disappears slowly and inexorably with the oldest whistlers.

4.2.4.1 The Slow Death of the Béarnais Language of Aas, France

Before the two world wars, Aas was cut off from the world nearly completely because of its geographical isolation. In the 1960s, Busnel et al. (1962) had already found the whistled form of the language to be rarely practiced. Indeed, whistling has progressively been abandoned in Aas since 1925–1930, which corresponds to the beginning of the industrialization of the towns in its region. The rural exodus consecutive to each of the world wars considerably emptied the countryside. This had significant consequences for the practice of the "*sifflet*" because it was losing its purpose in town. In Aas, the youngest of the families who traditionally escorted the flock in transhumance during the winter progressively ceased to assume this task, and during the summer, the shepherds in high mountain pastures bought mechanical vehicles to increase their communication options. According to Arripe (1985), the war and the rural exodus were not the only factors responsible for the decline of the Béarnese whistled language; linguistic discrimination also played a major role:

> Everything has been implemented between the two wars and even after to ensure that the [local dialect] patois would be considered as a language off-the-law […] The deliberate banning of Béarnese in favor of excessive use of French excessively has had very negative consequences. […]. Of course, who was ashamed to speak *patois* was even more ashamed to whistle (Arripe 1985: 89–90).

For this reason, in 1959, when Busnel developed the first study on the subject, the "sifflet" was already experiencing a dynamic of vitality loss:

> The whistled language of Aas represents the remains of a communication system that formerly possessed all the characteristics of a language […]. But in fact, the survey showed that although some elders of the village were still capable of some combinations, most young people are only capable of recognizing typical stereotyped sentences belonging to their specialized activities.' (Busnel 1964: extract of the video's spoken commentary).

Consequently, the recordings made by Busnel and a few years later by two conservators of the "Musée des Arts et Traditions Populaires"[1] fixed the images and

[1] These collections have been recently transferred under the responsibility of the Museum of European and Mediterranean Civilizations (MuCem), a national museum recently launched in Marseille, France.

the sounds of the last good whistlers, who by that time were already old. This statement is all the more true because none of Aas's inhabitants pursued the practice of whistled speech or taught it to their children, despite the renewed interest of researchers and the media. The generation that was young during that period did not learn the technique. For example, René Arripe, a native of Aas, wrote an entire book on the subject in 1985 but did not learn to whistle his language, even though his father was a good whistler, as demonstrated in Busnel's recordings. In his monograph, Arripe considered this form of the language as already dead before that was effectively the case. In fact, the last good whistler, Madame Nétou Palas, died only in 1999, and she displayed a good whistling performance in the 1990s. The whistled language of Aas officially died only with her. By 2003, nobody was capable of successfully speaking with this technique, as far as we could observe. Since 2008, new local Béarnais speakers[5] have had to relearn the practice (see Sect. 4.3.2.3).

4.2.4.2 The Decline of the Greek Whistled Language of Antia

In the case of Antia, the decline of the activities that sustained the village economically and the significant rural exodus that has taken place over the last 20 years are about to put an end to the whistled speech practice (Kouneli et al. 2013). Currently, there are no more than 3–4 truly fluent whistlers, all of them quite old. It is generally thought that life in small, isolated villages such as Antia is almost impossible in modern Greece because livestock and agriculture are no longer professions that can sustain whole families. Moreover, until recently, people thought there were no realistic opportunities for young people in such villages. As in Aas, there has been a widespread depreciation of the rural populations and of their way of life. With the economic crisis striking Greek society particularly hard since 2008, some villages have tried to demonstrate that such a model of life is again viable, with the return of some families to rural life. Interestingly, some neo-rural villages have settled on Evia Island because it is near Athens and may represent a future for whistled speech practice. However, they have not yet transitioned to pastoral activities.

Until now, it has been the lack of opportunities in the village that caused the vast majority of Antia's population to abandon the village. According to the 2001 census, the population was 172 inhabitants, and in 2009, the inhabitants reported that there were no more than 50 permanent residents (Kouneli et al. 2013). Within such a small community, where communication over long distances outside the village and between houses in the village is no longer a problem, whistled language is not transmitted. Very young children do not have occasions to listen to whistled speech on a daily basis and no longer learn it. Moreover, at the end of 2004, the primary school in Antia closed (Meyer 2005). Consequently, all of the young students had to move to Karystos, the closest town, to be educated. Inhabitants between 18 and 35 years old are rare, except during school and university holidays.

Until recently, there was no initiative for teaching whistled speech to the young. The idea seemed curious to the locals, even in the primary school, where we showed examples of whistled speech from many other cultures around the world.

Despite this alarming situation, some people from outside the village have attempted to create incentives for the few remaining whistlers to transmit their practice. Tourism promotion might be one of the motivations, with all its drawbacks for the community.

A young student in linguistics from the small town of Karystos near Antia recently began to study the subject. Her proximity to the families of whistlers and her knowledge of the place might change the current situation, and she may rekindle the passion of the village's oldest members for their former way of life. The situation in Antia is critical and in this context, some actors have been inspired to take the initiative for a village revitalization project. Of course, revitalization of the whistled language is closely related to economic and cultural "revitalization" of the village, which is very difficult. Because most of the remaining whistlers of Antia are traditional good or very good whistlers, there is some hope that the revitalization will lead to some positive results if at least one of these whistlers actively participates in the revitalization process.

4.3 Documentation, Revitalization and Revival

4.3.1 Sketch of the Initiatives for Maintenance

Some communities have been concerned with safeguarding and transmitting their whistled speech practice because they consider it an important part of their oral patrimony and identity. However, it is difficult to maintain a tradition linked to disappearing traditional activities. As a response to this situation, local speakers—sometimes with the support of linguists—have developed various strategies and methodologies of documentation and revitalization. Such initiatives often lead to strong cultural and political debates because the options can be as diverse as including school instruction in whistled speech and building a multimedia database documenting the tradition. Although these activities do not replace the principal maintenance factor—the survival and valorization of traditional activities—they contribute to the reappropriation of the endangered oral patrimony.

For example, on the island of La Gomera, the first option has been applied with considerable success by some of the last traditional whistlers, who obtained the support of the regional government (see below). In the Mazatec region of Mexico, whistles were included in the cultural lessons introducing the Mazatec language in secondary school (Meyer and Casimiro 2008). Among the Gavião and the Surui of Rondônia, a documentation project of music and language involving younger

generations from within the community was launched, and whistled speech was documented. The local people wanted their music and traditional use documented by the Museu Goeldi. For linguists, whistling has been a key aspect of documenting the phonology of the tonal systems of these languages (Moore and Meyer 2014). The chosen documentation methodology consisted of building a bridge between old traditional speakers and the youngest generation by capturing audio and video and editing the data for the village during video-editing training courses. The language data were collected in both whistled and spoken form and were transcribed, providing teaching material for schools and documentation material for local associations and for digital language archives, such as the Museu Goeldi Indigenous Languages Archive (*Acervo de línguas indígenas do Museu Goeldi*, Belém, Brazil) and the Endangered Languages Archive (ELAR) (SOAS, London).

On La Gomera Island in Spain and in Kusköy in Turkey, some officials and whistlers have used whistled speech to incentivize folkloric tourism. Kusköy officials adapted their annual spring festival to celebrate their variety of whistled speech. The association in charge of whistled speech is called "Kuşdilini Tanıtma Kültür Ve Turizm Derneği". Local school children and the best whistlers are involved in this event, which has the advantage of giving the village national visibility and concentrating tourist activities within a specific period.

4.3.2 Teaching for Revitalization or Revival

When the situation is critical, for example, if nearly the entire population has lost a language practice, the motivation of a small group of persons has proved to be sufficient to initiate real revitalization processes (Nettle and Romaine 2000). In this section, we will explore two examples of maintenance initiatives at school: first, the case of the 2007 inscription of whistled Mazatec into a secondary school program in Mazatec-speaking regions for courses on Mexico's local cultures; and second, the case of the Canarian initiatives to preserve the whistled speech practice (locally called Silbo Gomero), especially the aspects related to primary school teaching, which was a key element in initiating a broader local process of revitalization. Interestingly, in both cases, linguists' phonetic analyses were used as an argument to justify the cultural and linguistic interest of whistled speech for language education. Whistling was presented as a natural support for students to didactically identify various phonetic aspects of their spoken language (for example, the tonal system in Mazatec or the perceptual reality of vowels and consonants in Gomero Spanish). We will focus on the analysis of the work of Trujillo et al. (2005) and Casimiro et al. (2007), which are intended to develop teaching methods while selecting scientific references.

4.3.2.1 The Example of Mazatec

In the Sierra Mazateca, a mountainous region in the northwestern part of the Oaxaca state of Mexico, we observed a great disparity of practice and interest in the whistled practice. One reason for this situation is that whistling is only practiced in the highest part of the Sierra Mountains. Another reason is that whistling is being progressively lost. Consequently, competences also change as a function of families and generations. In general, the Mazatec language continues to be largely spoken but is rapidly losing speakers to Spanish. This situation raised concern about safeguarding cultural particularities linked to the native language. For example, in 2003, the indigenous assembly of the district of Eloxochitlan de Flores Magon identified the use of the "lengua silbada" as among the community's cultural priorities, along with other aspects of the oral tradition, especially those linked to the preservation of local medicine and traditional land rights. This was possible because as of 1997, Mexico officially recognizes the possibility of the villages to organize themselves on the basis of their "usos y costumes", recognized in the "law on peoples" and indigenous communities' rights. Another initiative using whistled speech related to all of the districts where the Mazatec language is still spoken. It consisted of introducing the native language at school. Juan Casimiro Nava, a local writer and translator of Spanish books in the Mazatec language, is a retired school professor. He was in charge of educative missions at school for the Instituto Nacional Indigenista (INI) in 2003, 2004 and 2005, and in 2006, he was invited to participate in creating secondary school programs. In this context, he contributed to the introduction of Mazatec culture in the "curso de cultura" as part of the new "programa de lengua y cultura mazateca para la educación secundaria tercer grado" (Casimiro et al. 2007). Because the Spanish language remains the reference for school teaching in Mexico, the guidelines of the pedagogic program recommended clarifying the primary differences between indigenous languages and Spanish. In this perspective, the use of pitch for tones, which differs drastically from Spanish, was explained first by showing the students that the Mazatec language uses these tones to distinguish words. This occasion was employed to justify the use of an orthography that signals tones. Moreover, the pitch differences among tone levels were clarified through a reference to musical notes. Finally, to explain this aspect more concretely, whistled speech was then included in the course. Phonetically, it had the advantage of helping the children understand tonal levels and tonal glides (Meyer and Casimiro 2008). This didactic strategy could be now introduced into other tonal languages that have a natural whistled form, such as the Gavião and Suruí of Rondônia in Brazilian Amazon.

4.3.2.2 The Example of Gomero Spanish

The whistled Spanish of La Gomera, locally referred to as *el Silbo*, is the most famous (and most studied) whistled language in the world because it is situated in an accessible touristic area. Since the description of Lajard (1891), we have known

that *el Silbo* relies on an imitation of the Spanish language, and since Classe (1956, 1957), we have learned that a phonetic emulation of the segmental quality of consonants and vowels is the key to understanding the whistled form. A dozen publications have followed since then. However, despite this international and academic interest, whistled Spanish fell into disuse between the 1980s and the end of the 1990s. During that period, two old whistlers managed to convince their relations, and later the local government of the Canary Islands, to promote school teaching of *el Silbo*. Confronted with the local disinterest of their children's generation, they proposed skipping a generation and teaching it to the next generation. The debate has been long and the two whistlers, who gained the status of *Maestro de Silbo*, became benevolent teachers at school. During the 1990s, the local authorities began backing the initiative, and while helping make school teaching official, they launched a large campaign to promote Silbo, including diverse actions such as supporting a research initiative of local scholars (Carreiras et al. 2005), promoting the development of didactic materials (Trujillo et al. 2005), presenting Silbo on other islands and even hosting artistic events based on whistled speech. This was a drastic change in the use of whistling, and some authentic whistlers complained about a lack of consultation of the community and sumptuous financial disbursements. As part of a communication strategy of the government of the Canary Islands, all of these events increased La Gomera's media visibility, thus justifying European Union financial help for the island's various policies and promoting the island's cultural and ecological specificities through its UNESCO designation. For a long time, the initiative of teaching Silbo in school remained unique in the world. In 2009, after receiving intense regional and national support, the Spanish whistled form of La Gomera was inscribed on the Representative List of the Intangible Cultural Heritage of *Humanity*. Finally, some Silbo courses are currently being offered to the intermediate generation based on the community's years of experience teaching whistling to its children. Moreover, some Silbo whistlers have begun to develop their own courses on La Gomera Island, whereas others, through an association called *El Silbo Canario*,[2] have developed an entire program of whistled Spanish training on some of the other islands.

Interestingly, the process of developing didactic materials for teaching was not simple. The local authorities, wanting to base their analysis on researchers from the Canary Islands, chose the work of the only Canarian linguist who has tackled the subject (Trujillo 1978). Unfortunately, his analysis concluded with a vowel-analysis theory that proved to be false (see Meyer 2008, Chaps. 7 and 8). According to him, there were only two whistled vowels in the Silbo Gomero language instead of the four described by other linguists. For consonants, his simplification fit the phonetic descriptions made by other linguists. The theory of Trujillo had also been vigorously contested by a majority of native whistlers, including the two *Maestro de Silbo*. Some of the whistlers were afraid that an artificial, simplified form of the

[2] The association has even inspired a cell phone application called "Yo Silbo", which helps train people in whistled Spanish.

language would be taught to children. Consequently, the first edition of "*Materiales didacticos*", which contained this academic error, was partially revised in 2008. The revision related to a section written by the *Maestro de Silbo* Isidro Ortiz (Trujillo et al. 2005: 68), but in the other two sections, the mention of only two vowels remains (Trujillo et al. 2005: 32). Nevertheless, Silbo Gomero is currently taught by several schoolteachers, who have adopted strategies that avoid taking in consideration the errors in the written didactic materials. One Maestro de Silbo and teacher primarily relies on a traditional form of teaching by imitation. Two other teachers have combined the imitation model with a pedagogic discourse based on Isidro Ortiz's simplified explanation developed in the didactic materials cited above. Even if the whistled form of the language is on the way to being revitalized thanks to this initiative, the current social use of whistled speech has little to do with the conditions of the past, and the children's *neo-Silbo Gomero* will be interesting to follow. Gomeros are now generally proud of their Silbo and more and more people are able to utter sentences in whistled Spanish.

4.3.2.3 Revival in Béarn

Since 2008, Bearnais speakers have attempted to relearn the whistled speech practice. They contacted our research group called the "Whistled Language Unit", which Professor Busnel, his former engineer Mr. Gautheron and I created in 2007, and asked us to back their attempt to revitalize the whistled language by using existing recordings and linguistic analyses. Since 2006, an association called "Lo Siular D'Aas" has been working toward understanding and restoring the technique of whistling speech. They exploit the rare recorded documents collected at the time of Busnel and are helped by whistlers of other countries and the expertise of the authors of this monograph. Their efforts have begun to bear fruit because after having collected the ancient recordings and learned the whistled articulation of vowels and consonants with the help of whistlers of La Gomera in the Canary Islands and of Antia in Greece, the members of the association began to communicate whistling in their language. They managed to revive this practice. They affirm that their action was performed in the context of a participative research action (PRA) to contribute to the rediscovery and protection of their land's linguistic and cultural patrimony.

4.4 Conclusion

This chapter first presented a sketch of the different contexts of the use of whistled speech and explained why this practice is severely endangered. We analyzed the general factors of the decline and the maintenance of whistled language practices and discussed particular field cases to illustrate this analysis. The traditional activities that sustain whistled languages are central to the local economy of such

communities. Therefore, depreciation of traditional knowledge and of the associated way of life strongly affects whistled speech. We have shown that some whistlers' choices may be crucial for the maintenance of this practice. Defining whistlers' profiles has proven helpful for fieldwork and for understanding the dynamic of attrition. Because whistled speech dies before normal speech, the vitality of whistled languages represents a reliable human indicator of the vitality of the traditional way of life. We will further develop this aspect in Chap. 9. The surviving competent whistlers, although often illiterate, maintain a large span of the oral patrimony of their culture because their life remains tightly linked to traditional rural customs requiring the use of whistling. For these reasons, these speakers are capable of playing an important role in potential language revitalization projects or for ecological knowledge documentation (to understand the vast lexicon of terms for species and natural phenomena). We presented original revitalization initiatives that illustrate the possible use of whistled speech to reinforce language teaching. Whistled talk now survives only as a sporadic practice limited to a few valleys or very traditional villages, and whistlers are now rare everywhere in the world. To the outside observer, whistling is relatively unnoticeable unless he or she follows the villagers in their everyday activities and asks questions about it.

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Chapter 5
Whistle Production and Physics of the Signal

This chapter explores various acoustic aspects of whistled languages. We first describe the different whistling techniques found around the world. Next, explanations of the mechanism of whistle production are offered. Meanwhile, we present the basic physiological factors that enable whistlers to speak while whistling. We also characterize the general physical properties of a whistled speech sentence in the frequency, amplitude and time domains of sounds. A comparison with the human voice is provided to highlight differences and similarities, particularly between whistling and the sung and shouted voice.

5.1 Whistling Techniques

Many techniques have been described among the populations that whistle their language. The choice of a specific technique initially depends on practical concerns. It is strongly influenced by the dominant range of communication. Bilabial whistling is common for short distances (up to 50 m in quiet, flat, small villages). To reach high levels of power for medium—or long-distance speaking, the tongue is retroflexed, one or two fingers are placed in the mouth, the lower lip is pulled while breathing in air, and the blowing is concentrated at the junction between two fingers or in a cupped hand.

Each place has its favorite trend that depends on the most common use of the village, on the ecological environment and on the personal preferences of each whistler. For example, bilabial whistling is mostly found among the people who use whistled speech inside villages or small towns at rather short distances, such as the Mazatec, the Chinantec, the Yupik, the Wayãpi and the Gavião (Fig. 5.1). For example, the Mazatec and Chinantec living in towns use it for discussions in a market, in the noise of a restaurant, in the streets to call someone or at night with their neighbors (Fig. 3.9). Bilabial whistling is also commonly used during hunting by the Surui of Rondônia and by the Wayãpi of Amapa (Brazil)/French Guiana, most likely because it enables discreet communication in the presence of prey. This bilabial whistle is never used in La Gomera, Aas or Kuskoy, at least for the purpose

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Fig. 5.1 Bilabial technique. **a** Mazatec whistler of Huautla de Jimenez (Mexico), **b** Yupik whistler of Savoonga (Alaska) [*Photo a* Courtesy of Julien Meyer/Laure Dentel (© Julien Meyer/Laure Dentel. All Rights Reserved), *Photo b* © Rolex Awards/Jacques Bélat. All Rights Reserved]

of speech communication, undoubtedly because the decibels that it produces are insufficient to reach long distances in the mountains.

The most widespread medium- and long-distance whistling technique consists of the linguo-dental production of whistles. This method is characterized by the tip of the tongue being retroflexed against the lower incisors, forming a small aperture in the middle. The lips, generally rather spread, adhere firmly to the anterior surface of the teeth (Figs. 2.1 and 5.2). This technique can be found in many places around the world, including the Atlas Mountains of Morocco, Evia Island in Greece, the Sierra Mazateca of Mexico and the Turkish region of Kusköy. There are several advantages that account for its wide use: the hands stay free for other activities, the whistling is powerful and it is easier to pronounce certain phonemes such as those requiring the closure of the lips (such as /p/ on Fig. 5.12). There are variants of this technique. For example, some Turkish whistlers occasionally increase the power and acuteness of the whistle by pressing a finger against the tongue (Fig. 5.3a, c).

For long-distance one-finger techniques, any finger is suitable, whether curved or not (Figs. 5.3 and 5.4). The finger presses upon the blade or even farther back at the beginning of the front of the tongue. The curved index is the most widespread technique of La Gomera Island. The bent auricular technique was more common in Aas in Bearn Pyrenees (Fig. 5.4a) and is still used among the Chinantec in the town of Sochiapam. The air stream is forced over the middle knuckle that lies across its path and emerges from the central opening of the lips contracted in the usual way. The lips are in contact with the front teeth, and with the finger, they form a small

Fig. 5.2 Linguo-dental technique with the tip of the tongue being retroflexed against the incisors. **a** Mazatec whistler (Mexico), **b** Tamazight whistler (Morocco), **c** Turkish whistler of Kusköy, **d** Whistler of La Gomera Island (Canary Islands) [*Photos a*, *b* courtesy of Julien Meyer/Laure Dentel (© Julien Meyer/Laure Dentel 2015. All Rights Reserved), *Photos c*, *d* courtesy of René-Guy Busnel (© René-Guy Busnel. All Rights Reserved)]

aperture. It can be seen that in any case, the air path is far from rectilinear. This is also the case for the very powerful two-finger techniques that are used by some Greek, Gomero, Turkish, Béarnese, Mazatec and Yupik whistlers when very isolated. The most common combinations of fingers are the thumb and index fingers of the same hand or those using the two index or the two auricular fingers. In either case, the two fingers form a V pressing on the tongue (Fig. 5.5).

Other long-distance techniques, such as pulling the lower lip and breathing air in simultaneously, which were found among the Mazatec of Mexico, are less common (Fig. 5.6).

Some "hand-whistling" techniques use a resonating cavity inside one or two hands to produce sensibly lower frequencies and a larger frequency bandwidth than all of the other techniques. They are often associated with an ecological milieu characterized by dense vegetation (e.g., Amazonia). The following are some such techniques that we observed: cupping one hand (as among the Gavião of Rondônia, Fig. 5.7b, d), joining the hands together [as among the Bench of Ethiopia (Wedekind 1981) or among some Akha subgroups of Laos (Meyer 2005)] or

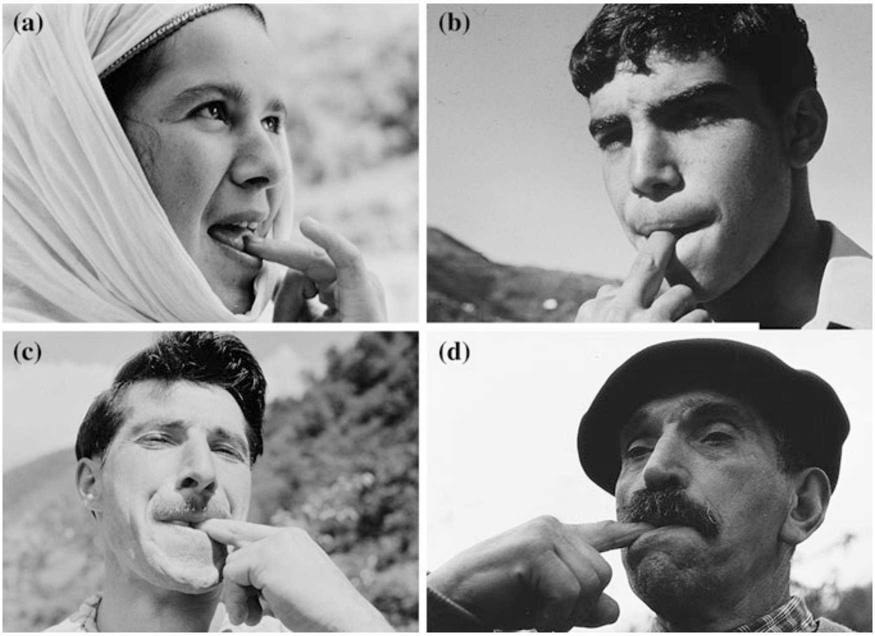


Fig. 5.3 One finger technique, not bent. It might be used in complement to the linguo-dental technique (**a**, **c**) or by pressing on the tongue farther back (**b**, **d**). **a** Turkish whistler showing how the finger is positioned against the tip of the tongue, **b** Gomero whistler, **c** Turkish whistler, **d** Bearnese whistler of the Pyrenees (France) [*Photos a, b, c, d* courtesy of René-Guy Busnel (© René-Guy Busnel. All Rights Reserved)]

forming a hole between the membranes of two fingers of each hand (found among the Ari of Ethiopia, the Banen of Cameroon (Dugast 1955) and the Gavião of Rondônia (Fig. 5.7a, c)).

Wooden, ivory or horn whistles were once common in Africa (see Sect. 2.2 of Chap. 2, Fig. 2.3), where they were primarily used for communication in savannas and forests and for singing. Just as with hand whistling, they produce whistles with low frequencies and large bandwidths. In Andalusia (Spain), a very particular whistle made of clay or wood is introduced inside the mouth and creates an artificial whistling palate to speak at long distances (see Figs. 3.6, 5.10 and Sect. 5.2).

In Asia, leaf whistling is widespread and is often associated with the *whistled mode of singing* (alternatively called *singing mode of whistling,* see more details in Sect. 5.4.2). Indeed, whistling with a leaf (Fig. 5.8) or a flute (Fig. 5.9) is often related to courtship or poetic expression (reported in the Kickapoo language in Mexico (Ritzenhaler and Peterson 1954) and in the Hmong (Brunet 1972; Busnel et al. 1989; Meyer 2005), Akha (Meyer 2005) cultures in Asia).

Fig. 5.4 Bent finger technique. **a**, **b**, **c** Gomero whistlers, **d** Bearnese whistler. The Gomero whistlers sometimes use the other hand to direct the sound coming out of the mouth in the right direction (**b**, **c**) [*Photos a, b* © Rolex Awards/Jacques Bélat. All Rights Reserved, *Photos c, d* courtesy of René-Guy Busnel (© René-Guy Busnel. All Rights Reserved)]

5.2 Physiology and the Physics of Whistling Production

As we began to see in the previous paragraphs, whistling techniques do not require the vibration of the vocal cords. In fact, whistling with simultaneous phonation is technically possible but very unstable and does not allow a powerful sound. Such a practice was never used by the people we met. A human-made whistled speech signal is produced by the compressed air stream inside or at the entrance of the oral cavity (or eventually inside a cavity made by the hands or a carved/manufactured whistle). It is very different from the human voice both in its mechanism of production and in its acoustic form. A whistle consists of a simple narrowband melodic line modulated in frequency and amplitude. The difference is most notable at the frequency level of the signal because the voice shows a complex distribution in frequency. In the human voice, the vibration of the vocal cords determines the

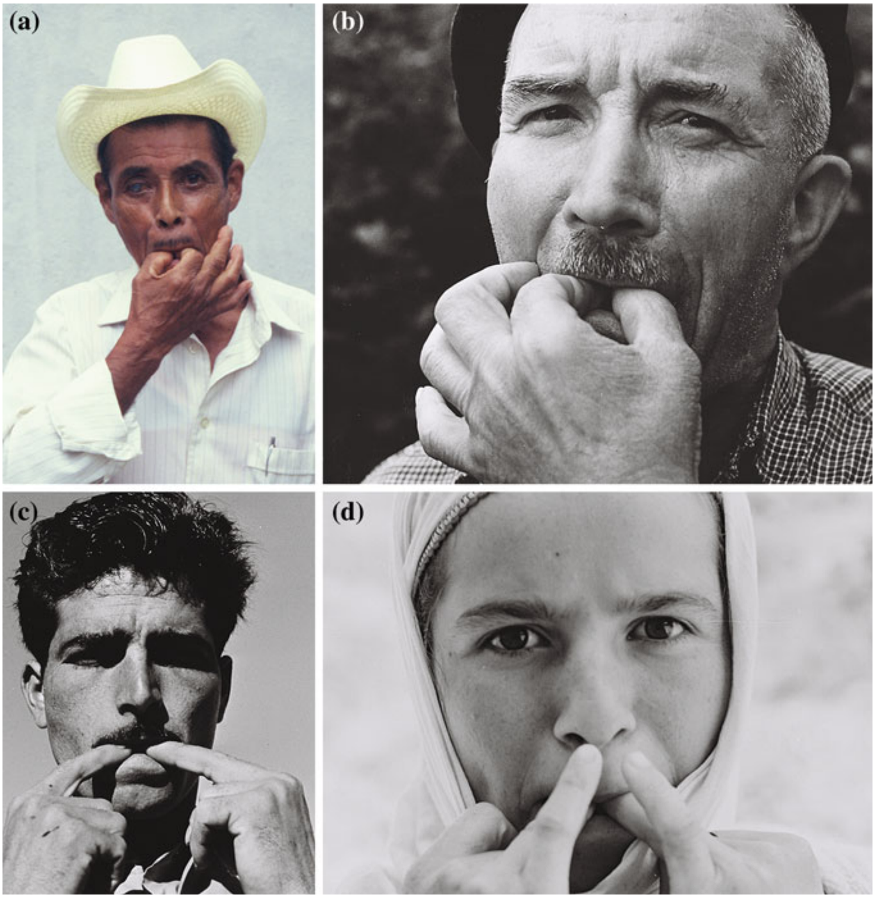


Fig. 5.5 Techniques with two fingers **a** Mazatec whistler, **b** Bearnese whistler, **c**, **d** Turkish whistlers [*Photo a* courtesy of Julien Meyer (© Julien Meyer. All Rights Reserved), *Photos b, c, d* courtesy of René-Guy Busnel (© René-Guy Busnel. All Rights Reserved)]

fundamental frequency and therefore, the pitch at which we speak. The vocal tract acts as a resonator to the harmonics of the vocal folds' vibrations, which are either scattered or reinforced, forming concentrations of energy called formants that are important for identifying vowels and consonants. This effect contrasts with what happens in whistling, where the fundamental frequency carries all of the useful linguistic information, emulating either the formants of the voice (for most non-tonal languages) or the pitch (for tonal languages).

Physicists have described how the air flowing through a constriction can produce whistles. The acoustic mechanism depends on the instability of the jet, resulting in a periodic generation of vortex rings. The sound generated by the vortices acts to increase the oscillations of the jet, thus closing a feedback loop (Shadle 1985). This type of mechanism is not limited to a jet emerging from a single constriction. It has

Fig. 5.6 Technique consisting in pulling the lower lip and breathing air in simultaneously. This technique is widely used in Latin America for whistling non speech codes. We found it associated to speech only among the Mazatec [*Photo* courtesy of Julien Meyer (© Julien Meyer. All Rights Reserved)]

Fig. 5.7 Techniques used among the Gavião people of Rondônia (Brazil) [*Photos a, b* reproduced from Moore and Meyer (2014), *Photos c, d* reproduced from Meyer (2012)]

Fig. 5.8 Whistled leaf technique shown by a Akha couple (*Photos* © Rolex Awards/Tomas Bertelsen. All Rights Reserved)

Fig. 5.9 Flute technique used for singing. **a** Gavião musician, **b** Akha musician Aju Jupoh [*Photo a* reproduced from Meyer and Moore (2013), *Photo b* © Rolex Awards/Jacques Bélat. All Rights Reserved]

been shown to operate in several other typical configurations, and it is possible to predict the frequencies generated by such flows (such as in a hole tone or when a jet strikes a wedge, the edge of a cavity or a ring). The physics of whistling production with the Andalusian whistle is interesting to understand: due to the use of a tool, the entire process can be easily linked to a mechanical model. This tool has holes in two parallel plates (Fig. 5.10). Any whistle produced by this type of geometry is called a

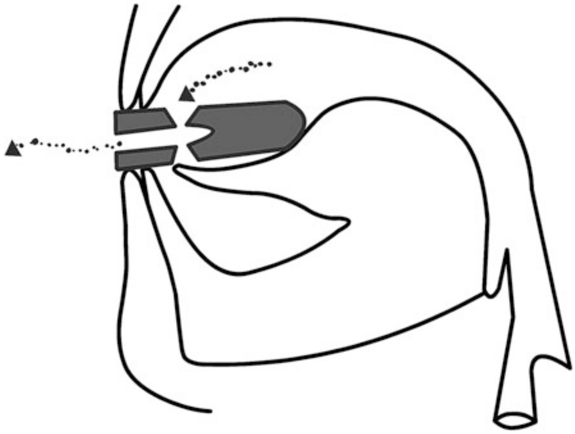
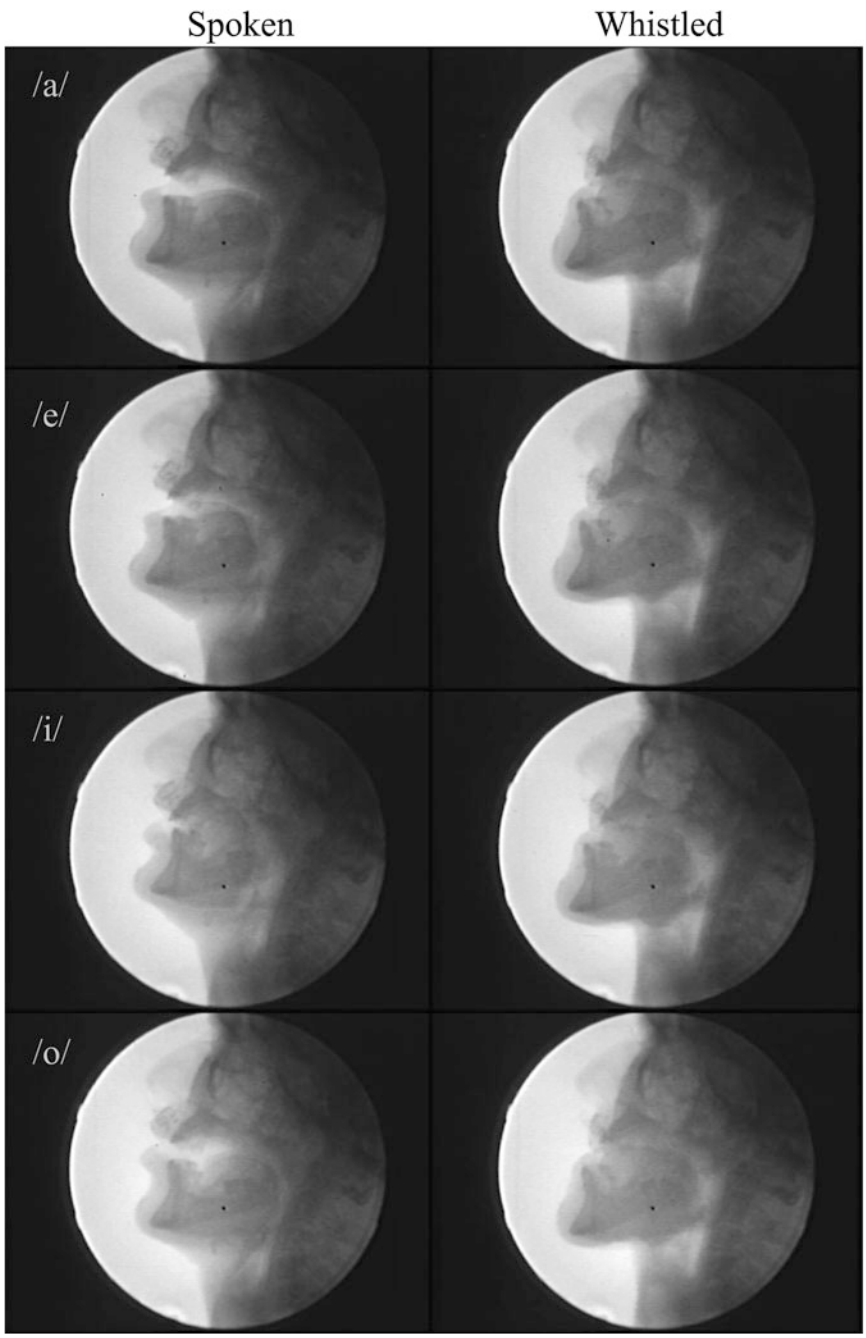


Fig. 5.10 Position of the *pito* or *boca* whistle in the mouth. The *arrows* indicate the curse of the main air flow

hole tone and therefore can be well approximated by the hole tone model, which is characterized by air passing through axial holes in two plates spaced slightly apart (Chanaud and Powell 1965). The first hole creates a high-speed jet of air that produces a whistle when it is forced through the second hole if the flowspeed and the diameter cause the jet to be in the unstable range. The frequency of the hole tone depends on the distance between orifices, the jet velocity and, eventually, the resonant structure controlling the feedback. Interestingly, Wilson et al. (1971) undertook a study on whistling by mouth in which they modeled the human whistle as a hole tone problem with the orifice plates replaced by thicker constrictions with rounded edges (representing the throat and mouth). They concluded that human whistling falls into the same class as the hole tone. They also showed through experimental investigation that a Helmholtz resonator could be constructed using a volume between two constrictions with a net through-flow. This confirmed some aspects of earlier investigations on human whistling made by Rayleigh, who had determined that the governing mechanism was that of a Helmholtz resonator (Rayleigh 1945). Moreover, Wilson and his colleagues also found that a coupling of the Helmholtz resonator with the resonant modes of a duct attached to the second hole may be significant, modifying the frequency of the final whistle. This effect is probably why Andalusian whistlers can modulate their whistles by modifying the chamber of resonance below the second hole of the "pito" (Fig. 5.10).

For human whistling without modeling, it is much more difficult to measure flow velocity or articulatory dimensions with precision, making frequency predictions difficult to check. However, the typical bilabial whistle has been described quite precisely by Shadle (1983). She has shown that the typical bilabial whistle produces frequencies from 0.5 to 4 kHz, finding that this frequency is primarily controlled by the anterior-posterior position of the constriction formed by the tongue. Shadle also has proven experimentally that peaks in the source spectrum of whistles are greatly amplified by the cavity and that the source and resonator become coupled so that the source frequencies no longer vary freely. This phenomenon explains our observations that if the orifice (shaped by the tight lips and eventually a finger) and the cavity


Spoken
Whistled
/a/
/e/
/i/
/o/

◀**Fig. 5.11** X ray still images of sustained Turkish vowels /*i*, *e*, *a*, *o*/. Acute whistles (/*i*/) are produced with a tongue in an anterior and high position, intermediate frequencies are produced with a tongue in high position, lower frequencies (such as for /*o*/) are produced with a lower and more retracted tongue [*Photo* reproduced from videos of Busnel (1968)]

(intra-oral volume) are well matched, the resonance is tuned and the whistle is projected more loudly (Meyer and Gautheron 2006). Because the tongue position also determines the frequencies of the second and third formants in the human voice and because frequency jumps between these formants have been observed in whistling when the velocity of the flow increases, it appears that the whistle frequency is always captured by either the second or third formant of the vocal tract (Shadle 1983). The process she described for frequency jumps is as following: as flowspeed increases, the whistle frequency will increase only slightly until the characteristic frequency is closer to the next higher cavity resonance, at which point the whistle frequency will jump upward and couple with the next higher mode. According to that author, this effect primarily occurs when the formants are close.

Although these observations leave the exact mechanism of each human whistle technique unclear, human whistling does exhibit behavior very similar to that of the mechanical whistles that have been extensively studied. Some techniques of whistling reach sound production only with a very high velocity of flow (finger techniques, for example), whereas others require much less velocity (those for close range, such as the bilabial technique). To control whistling air flow, whistlers combine the movements of the lower jaw, which is tensed forward (which makes a large cavity in the larynx), with those of the tongue and the glottis. As we have just seen for the bilabial and the Andalusian whistling techniques, the frequency of this acoustical phenomenon is modulated by the morphing of the resonating cavity, which can be, to a certain extent, related to the articulation of the equivalent spoken form. Examples of X-ray video images confirm this (see Busnel 1968 to observe the compared dynamics of articulation of strong speech and whistling; see here examples of still images extracted from these videos in Figs. 5.11 and 5.12). The larynx is maintained large and the resonators are mostly shaped by how the tongue modifies the hole producing the whistle (in front of the mouth near the contact with the lower incisors in Figs. 5.11 and 5.12). Therefore, it is the movement of the top of the tongue or of the point where the finger(s) press on the tongue that are important. In non-tonal languages, vowels and consonants are produced by positioning the tongue and the vocal tract in ways that approximate the articulation of ordinary speech. Acute whistles are produced in the front of the palate with the tongue in an anterior and high position (such as for /i/); lower whistles resonate more in the back with a lower and more retracted tongue (such as for /o/) (Fig. 5.11). In tonal languages, the different tone levels, tonal modulations and contour tones are obtained the same way. In all cases, the glottis controls the compression and the release of the air that is essential to produce certain consonant closures (complete or partial) together with a strong blow in both types of speech registers.

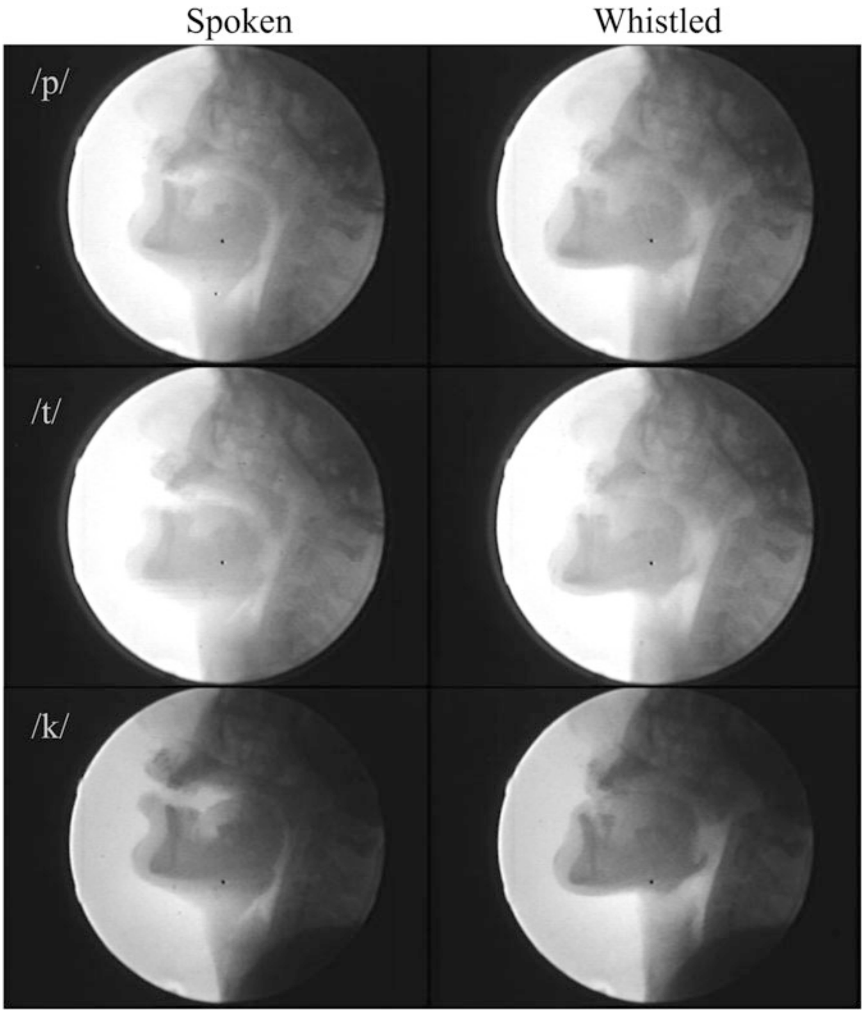


Fig. 5.12 X ray still images of consonants /*p*, *t*, *k*/ just before explosion and articulated by a Turkish speaker [*Photo* reproduced from videos of Busnel (1968)]

5.3 Acoustic Characteristics of Human Whistled Languages

5.3.1 Typical Frequency Bands of Human Whistled Speech

When considering all of the languages and all of the whistling techniques, whistles range from 0.9 to 4 kHz, much less than the frequency band covered by the human voice (0.1–16 kHz) or even by the typical band of the telephone, which focuses on the frequencies that have been found by telecommunications engineers to be the

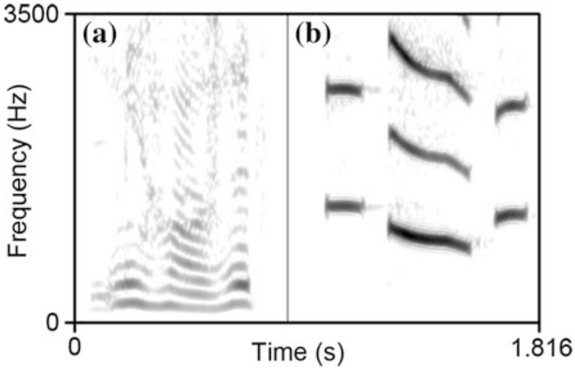


Fig. 5.13 Extract of a whistled leaf message in the talking mode of Akha language, where there is no ornamentation (syllables [mí ɣà ɣý], written "*mir gangq goer*" in the Akha unified Romanized Popular Alphabet). **a** Spoken form, **b** Whistled leaf form

most useful for intelligibility (from 0.4 to 4 kHz). The pitches of whistles are concentrated in a narrow bandwidth where the hearing in human beings is more sensitive and selective (see Chap. 8). There are various factors of variability influencing this frequency band. First, the stronger the whistle produced by the chosen technique, the higher the mean frequency of the entire production. For example, in Silbo Gomero, we found an increase of 250 Hz between whistled sentences meant to reach receivers situated at 100 and 500 m. Another factor concerns the type of language that is emulated. For example, non-tonal whistled languages may cover over 2 octaves for the same whistling technique (0.9–3.8 kHz in La Gomera with Spanish, 1.2–3.5 kHz in Aas for Béarnese (Busnel and Classe, 1976), 1.4–4 kHz in Kusköy for Turkish and 1.2–3.4 kHz in Antia for Greek). The range of whistles in tonal whistled languages is narrower and never exceeds one octave in the same sentence produced with a given whistling technique (1–2 kHz in Mazatec, 1–2 kHz in Suruí of Rondônia, 0.8–1.5 kHz in Akha and 0.9–1.5 kHz in Hmong). This difference is explained by the fact that different parts of the human voice are emulated in tonal and non-tonal languages. In the human voice, the range of pitch variations is narrower than the range covered by timbre. This difference is mirrored in the whistles emulated by these different frequency levels of the voice. In the singing mode of whistling practiced with the leaf by the Akha people, it is common to find an aesthetic effect called vibrato (Fig. 5.13).

5.3.2 Typical Amplitude Variations

When a whistler wants to reach a faraway interlocutor, his whistles can easily reach maximum levels of amplitude of approximately 120 dB (at 1 m) with finger techniques. Maximum amplitudes are more commonly approximately 100 dB with

the whistled leaf, the Andalusian whistle or the linguo-dental technique. For middle-distance communications (approximately 200 m), levels of production are approximately 80–90 dB. The different peaks of energy of the amplitude envelope of a whistled sentence represent the different syllables, just such as in spoken speech, but with a clearer segmentation. We will see later that other fine aspects of the amplitude envelope help whistlers separate consonants into various classes (continuous, near-continuous or clearly interrupted signals; see Chap. 7).

5.3.3 Duration of Vowels

The clearer segmentation generally noted for whistled words indicates that they are often uttered more slowly than spoken words. This affects mostly silent durations between speech groups and vowel durations. In the languages that do not have phonological distinctions in vowel quantity, the duration of any vowel may be adapted to ease the intelligibility of the sentence. For example, for a dialogue at a distance of 150 m between interlocutors, the vowels were measured to last an average of 26 % longer in whistled Turkish than in spoken Turkish and 28 % longer in Akha of Northern Thailand. Some differences may appear as function of the individuals, as shown by Moles (1970) in whistled Turkish, because the speakers maintain proper elocution characteristics during the whistled articulation. At very long distances (several kilometers) or for the sung mode of whistled speech, the lengthening of the vowels can reach a mean of 50 %, with some vowels much more emphasized than others. The vowels with a very long duration are mostly situated at the end of a speech group: they help sequence a sentence rhythmically in coherent units of meaning. In this way, contrary to what occurs in the singing voice (see Sect. 5.4.1.3), such exaggerated durations do not reduce intelligibility but improve it.

5.4 Comparison with Shouted and Sung Speech

5.4.1 Strategies to Reach a Distant Listener/Audience

5.4.1.1 Control of the Source

In whistling and professional singing, mastering the technique of production requires a phase of learning in addition to the implicit acquisition that people acquire by growing up in linguistic communities or families that extensively use singing or whistled speech. Shouting is generally developed from birth without any particular distinct extra learning. In each of these three speech registers, an efficient emission relies on a homogeneous, powerful, relaxed and precise control of both the airflow and the physiological constraints imposed by word articulations. Compared

to standard speech, they all increase muscle tension in the vocal tract. These tensions reinforce the concentrations of energy in the signal because in addition to the shared (in some cases) aesthetical exigencies of whistled and sung speech, they all have the common aim of carrying oral sound across distances to ensure good communication (with a general audience in singing). As a sound source, the sung and the shouted voice use the vocal cords and a vocal tract often modified by a low and large pharynx. The resulting signals bear complex frequency spectra characteristic of the human voice.

5.4.1.2 From Standard to Shouted Speech… Toward Whistles

In shouting, to increase the range of ordinary speech or to overcome noise, individuals adjust their voices by raising amplitude levels in a quasi-subconscious way. During this vocal effort, called the "Lombard effect" (Lombard 1911), the spoken voice progressively passes into the register of the shouted voice. Effort is also intensified with the tendency to prolong syllables, to reduce the flow of speech and to increase the fundamental frequency. There is a large body of literature on this phenomenon for speech under noisy conditions (e.g., Dreher and O'Neill 1957; Garnier and Heinrich 2014). However, there are far fewer studies on variations in talker-to-listener distance in natural outdoor conditions (Meyer 2008; Cheyne et al. 2009; Fux 2012). The studies that address distance shouting all find that the fundamental frequency (F0) increases regularly with distance, parallel to an intensified vocal effort. For example, Cheyne and his colleagues find that F0 is increased by approximately 40 Hz when distance is doubled at distances between 1 and 32 m. The data of Fux, measured for distances between 2 and 100 m, provides approximately the same results. Fux also finds that most of the increase in duration is carried by vowels. The analysis of Meyer (2008) is performed from the viewpoint of the receiver of the message. Therefore, he analyzes the 2nd harmonics because they stand out the best from natural background noise. His results show a quasi-linear increase of frequency between 50 and 300 m (in an open valley and in natural quiet conditions). In this study, tiring of the vocal folds occurs at approximately 90–100 dB for a distance of 200 m. Beyond that limit, the speakers attempt to compensate with a drastic lengthening of the vowels and with a type of screamed voice. Due to the biological limits of the vocal folds, most shouted dialogs are brief.

From these observations, we can observe that whistled speech, which is typically produced between 80 and 120 dBA in a band of frequencies from 1 to 4 kHz and at a general flow from 10 to 50 % slower than standard speech (Moles 1970; Meyer 2005; Meyer and Gautheron 2006), implements a similar acoustic strategy to the one of shouting, consisting of increased intensity, frequency and duration. However, it does so without requiring the vocal folds to vibrate. It is a natural alternative to the constraints observed for shouted speech (tiring of the vocal folds). The three fundamental parameters of speech can be more comfortably adapted to the distance

of communication and to the ambient noise. Whistled speech is so efficient that full sentences remain intelligible at distances ten times greater than that of shouted speech (Meyer 2008).

5.4.1.3 Vowel Lengthening in Singing

The sung form of speech is also characterized by an increase in vowel duration in most of the singing styles. This results from the combination of many parameters that influence production in the singing voice. First, artistic choices justify this strategy, for example, to control the homogeneity of timbre quality, especially in the *bel canto* technique (Woisard-Bassols 2001). Moreover, a slower tempo is often inherent to music, resulting in a slower rate of speech. Next, articulatory movements last longer because of their greater range of variation (Scotto di Carlo 2005a). Finally, this phonetic approach partially relies on the fact that it eases the perception of voice quality and therefore favors comfortable listening. In a manner similar to what occurs in shouted and whistled speech, vowel lengthening may represent an adaptation to difficult communication conditions. Within certain limits, this phenomenon increases intelligibility. However, when the duration of the vowels exceeds a tolerance threshold, the ability to recognize the speech decreases (Scotto di Carlo 2005b). This is in contrast to what occurs in whistling, where such exaggerated durations do not reduce intelligibility, but ease it.

5.4.1.4 Actors' or Singers' Formant

The acoustic strategies of whistling, singing and shouting share a common behavior in a significant band of frequency between 2 and 4 kHz. A trained singer's singing voice shows a concentration of energy in this frequency range, especially for classical operatic singers of Western music. It is formed by the proximity of two or three of the formants 3, 4 and 5 or by the amplification of one of the formants already situated in this frequency domain. It has been called the "Singing formant" or "Actors' formant" and is sufficiently compact to favor a perceptive integration of the frequencies concerned (Bartholomew 1934; Sundberg 1972; Sundberg 2001). This energy concentration is also highlighted by studies dealing with shouted voices in a noisy environment. For example, speakers are found to boost their speech spectrum at values of approximately 3 kHz by Garnier and Heinrich (2014).

There are two justifications for the choice of these bands of frequencies: first, these bands place the signal above most of the concurrent frequencies of the performers' environment; second, they cover a domain that corresponds to the region of maximum ear sensitivity. Consequently, the signal-to-noise ratio (SNR) at reception is sufficiently high for good perception. For example, in the case of singing, (Pierce 1983; cited by Woisard-Bassols 2001) shows that perception of a singer's voice above a chorus or an orchestra relies essentially on the singing formant. He measures the peak SNR (2,500 Hz) for a tenor voice at approximately

30 dB. Similarly, as was explained in Sect. 5.4.1.2, whistled and shouted signals remain largely above the natural background noise at relatively long distances. For example, an equivalent SNR of 30 dB was measured in the frequency band of whistles approximately 200 m from the whistler for a sentence produced at 90–100 dB in a quiet environment (approximately 40 dB of noise). In addition to these common approaches, singing and shouting show differences from whistling that are due to their different sound sources. For example, both sung and shouted speech show strong amplifications around formant 1.

5.4.2 Influence of Language Phonology in Singing

In a similar manner to whistled speech, the contributions for encoding the word meaning of both the Fo and the *formant distribution* may influence the composition and the interpretation of songs. However, due to the complex frequency spectrum of the singing voice, testing this aspect is less simple. Furthermore, other parameters must be considered. Sung speech is not solely focused on intelligibility because it also takes into account artistic priorities that might interfere with the phonetics and the identification of words. For example, in operatic singing, a soprano voice is much less intelligible than a bass voice (Scotto di Carlo 2005a). Moreover, within a language, there may be a wide range of variation among different styles of songs, some having been borrowed from other cultures.

For the singing voice in non-tonal languages, research has logically focused on understanding the aspects of formant distribution that influence intelligibility (Gottfried and Chew 1986; Scotto di Carlo 2005a). One of the primary results is that the higher the pitch, the more difficult the identification of the phonemes. Moreover, the difficulty in identifying the vowels in sung speech has also been attributed to formants 2 and 3 as being less phoneme-dependent than in spoken speech. Interestingly, these results underline that intelligibility is advantaged when the frequency spectrum shows compact formants with a phoneme-dependent distribution. Such a conclusion is consistent with the fact that human perception is sensible to formant proximity, especially for identifying vowels (Chistovitch and Lublinskaja 1979; Schwartz and Escudier 1989). For whistled speech such proximities explain the association of whistled vowels to their spoken forms, even for naïve listeners (see Chap. 8).

In the case of tone languages, the Fo parameter of the singing voice is easy to test. For example, Wong and Diehl (2002) investigate Cantonese songs to further understand how songwriters cope with the double role of F_0 variations, that is, its linguistic role in expressing a lyric versus its musical role specifying melodic intervals. According to their preliminary inquiry, there are three options: "*The first is to ignore lexical tones and word meaning and to use pitch exclusively to mark the melody. […] The second option is just the reverse: to preserve the normal pitch variations of lexical tones while ignoring the melody, sacrificing musicality for intelligibility.[…] The third option is intermediate between the first two. […] This*

preserves musicality at the cost of reduced lyric intelligibility." (Wong and Diehl 2002: 203). These three options have been observed in several studies. (i) The first option preserves musicality at the cost of reduced lyric intelligibility. It primarily concerns fixed melodies imposed onto lyrics. Chao (1956) reports observing this phenomenon in Chinese contemporary songs. Similarly, Saurman (1996) measures the direction of pitch change over consecutive syllables in tones and song pitches: they match in only 32 % of the cases for the Thai national anthem and in 42 % of the cases for a foreign hymn translated into Thai. (ii) In the case of the second option, songs are very speech-like. This is the case of singsong themes in Chinese described by Chao (1956). Moreover, according to the description of Van-Khe (1997), this option generally concerns a large body of traditional popular songs in Vietnam and of several cultures of Southeast Asia: "*In the popular traditions of South-East Asia the improvisation is mostly poetic. The melody of the songs must follow the linguistic intonation of their text otherwise it would change the poetic signification*" (Van-Khe 1997). Saurman (1996) confirms this assertion for traditional Thai songs. Classical styles of singing are also performed using this option. For example, Yung (1983) finds a melody-tone relationship in Cantonese opera somewhat similar to what Chao (1956) reports in singsongs. (iii) In the case of the third option, "*songwriters may attempt to preserve at least partially the pitch contrasts of lexical tones while not unduly restricting the melodic role of F0 changes.*" (Wong and Diehl 2002: 203). Wong and Diehl prove that this strategy is at play in several contemporary songs in Cantonese. They show that composers and singers of contemporary songs in tonal languages often encode melody and meaning in singing using the same physical parameter (Fo). They also prove that corresponding strategies are used by listeners of tonal languages to extract the lexical meaning of the lyric: listeners apply an ordinal mapping rule in assigning tone categories.

5.4.3 The Sung Mode of Whistled Speech

The sung/singing mode of whistled speech is a practice that consists of emulating the sung voice while producing a whistled sentence. It is not an aspect extensively developed in all of the cultures that use whistled speech. It seems to be much more common in tonal languages, likely because such languages partly encode melody and meaning in singing using the same physical parameter (Fo, see preceding paragraph). Usually, repertoires of old popular songs utilize this practice, although the practice is sometimes adapted to contemporary songs.

As a first example, we present Akha singing mode of whistled speech, which is most of the time whistled using a leaf, either reciting verses or singing them. Akha is a three level tone language (high, mid, low with mid and low that can be laryngalized) of Southeast Asia for which whistled speech primarily transposes the pitch of the voice. It has a very rich oral repertoire of songs. Some of them, such as love songs, are more often used with whistling because the sung leaf is popular for

courtship. Because the aim is to transmit a poetic message, the melody of the songs follows the phonologic rules of the Akha tonal system. This way, the lyrics of the songs remain recognizable through whistling. The acoustic propagation of this type of signal enables the message to easily reach a distant lover, even inside his/her wooden house and to be more anonymous to others. The whistlers also say that whistling is very aesthetic. Indeed, several acoustical features are consistent with this last justification. First, whistling with an instrument such as a leaf gives more sound energy to the harmonics (Figs. 5.13 and 5.14). Next, in comparison with the talking mode of whistling that also exists among the Akha (see Fig. 5.13) the singers use classical techniques of ornamentation: they combine vowel-lengthened durations with vibrato (Fig. 5.14). Finally, the singers impose a modified rhythm onto their whistled productions: the rhythm is often iambic, with poetic stress marked by a lengthened duration. Tone perception is not blurred by the oscillations produced by the vibrato because these do not transcend the median frequency of the interval that separates two tones (the tones of the same sentence do not overlap even in vibrato, Fig. 5.14).

We also documented the sung mode of whistled speech among the Gavião and the Suruí of Rondônia, the Bora of West Amazon and the Teko of French Guiana. For example, some rare Suruí speakers remember ancient whistled songs depicting typical scenes of hunting or honey gathering that they whistle with the bilabial technique. The Gavião, Bora and Teko rather use a flute to play a whistled "instrumental form of speech". It is one of the most surprising type of instrumental music because the instrument is said to be singing the song. This practice is an ancient verbal art that exists in several parts of the world (Meyer and Moore 2013). It represents an important part of the oral patrimony that is rapidly lost due to acculturation because the capacity to play instruments that imitate the sounds of associated songs requires a complex traditional knowledge involving mastering various different techniques that range from manufacturing the instruments to learning a large repertoire of ancient songs (often in an archaic speech form, providing access to historical aspects of the language) (Moore and Meyer 2014). The musical lyrics and tunes played with the *kotiráp* bamboo flute of the Gavião are

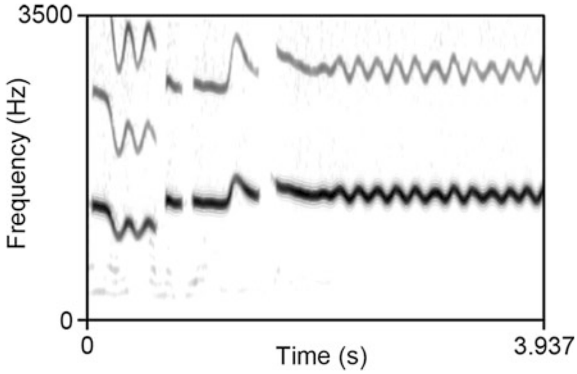


Fig. 5.14 Whistled leaf message in the singing mode of Akha language with examples of whistled vibrato

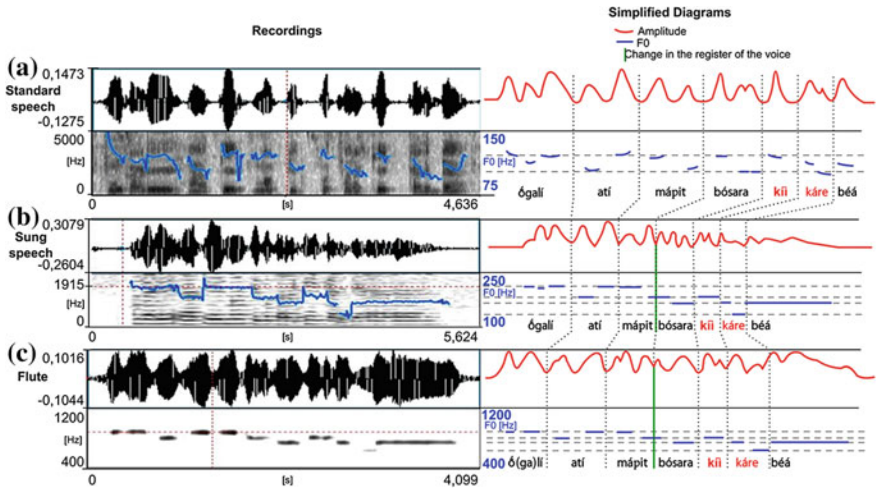


Fig. 5.15 Lyrics of a verse played on the *kotiráp* flute (meaning: *I will marry your daughter*): **a** Spoken form, **b** Sung form, **c** Whistled form. By comparing these three forms it is possible to investigate and describe the phonetic and phonological nature of the relation between the played melodies and the suprasegmental phonology of the corresponding words in both sung and standard speech. Even complex phonological rules such as *downstep* (syllables in *red*) are transposed in the flute melody [reproduced from Meyer and Moore (2013)]

characterized by a very tight music-lyric relation through pitch emulation. This music-language relation is important to explain through linguistic analysis because it justifies the Gaviãos' claim that the instruments are expressing the language, and more precisely, the singing mode of speech.

During our study, the recording and transcription sessions of music, songs and associated spoken sentences showed that this relation relies on the fact that Gavião language is characterized by distinctive tone and length where pitch carries both meaning and melody (Fig. 5.15). However, while listening to the played music, naïve listeners have rarely noticed that phonological aspects of the associated lyrics are reflected in the melodies (Moore and Meyer 2014).

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Chapter 6
Acoustic Adaptation to Natural Environments

A whistled speech signal is subject to attenuation and modification during propagation between the whistler and the listener. In general, whistlers have a profound knowledge of the impact of not only the terrain, the vegetation and noise but also local meteorological and topographical conditions on the intelligibility of both voices and whistles. This knowledge enables them to quickly evaluate whether the conditions of communication are optimal or difficult, allowing them to choose the most suitable whistle power to ensure a good understanding of their messages. In this chapter, we will review the acoustic constraints imposed by different types of environmental conditions and observe their effects on both the voice and whistles. All the spectrograms presented in this chapter were made with the same settings to enable comparison between different environmental contexts and acoustic effects.[1] Whistled speech is found to be particularly well adapted to rural environments, which have been the dominant setting for the vast majority of human evolution. Whistles may travel over long distances and, thus, may constitute an energy-saving substitute for movements across and within lands and for visual behavior that may be screened by obstacles or blurred by distance.

6.1 Background Noise

Background noise is ubiquitous in natural environments. Rural background noise is known to be rather variable, even when it does not include mechanical sources of noise. It depends on the geographical situation, the terrain, the vegetation, meteorological circumstances, bio-noises such as animal calls (biophony) and hydro-noises such as rivers or sea rumble (geophony). All of these biotic and abiotic sources define a wide and diverse span of situations, ranging from very noisy conditions to optimal ones. However, background noises in natural rural environments have common underlying basic properties that are well represented by the

[1] Hanning sine-square window (length of 0.025 s, time step at 0.002 s, frequency step at 20 Hz), dynamic range at 75 dB, maximum of 100 dB/Hz, pre-emphasis of 5 dB/oct, maximum frequency at 4 kHz.

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noise that remains when no geophony, no biophony and no anthropophony (human-made noise) interfere in the foreground with the quiet murmur of the background. This type of underlying background noise is called "natural quiet" in soundscape ecology studies. It is characterized by a nonuniform distribution of noisy frequencies that reflects the most regular noisy constraints encountered outdoors. An optimal natural quiet is generally found at night, when the power of sounds is low (often approximately 30–35 dB). In forests, natural quiet is rare during the day because of the activity of birds and insects. In temperate climates, its presence depends greatly on the season. A first important characteristic of such a typical "natural quiet" background noise is that it emphasizes low-frequency content. This is a general trend in every ecological milieu because low frequencies travel farther and are less attenuated by obstacles. A second important aspect is that power levels decrease rapidly as a function of increasing frequencies (Fig. 6.1). In the high-frequency range of whistles, a "natural quiet" noise is weak, so the signal-to-noise ratio of a whistled speech signal in natural ecological conditions remains generally high enough to be clearly heard at a long distance.

Most noise from abiotic sources has energy below 1 kHz. Rivers, torrents, waterfalls and sea rumble are important exceptions because they show strong amplitudes in the entire frequency spectrum (much as does white noise). For example, in the region of Turkey situated near the village of Kusköy, several villages are crossed by torrents that represent non-negligible sources of broadband noise that mask spoken and shouted communications nearby. Some activities, such as trout breeding, require proximity with the torrent. In the next valley east of that of Kusköy, a whistled speech conversation was recorded in May 2004 when the water flow was particularly strong (see photo Fig. 3.4a and sound recording Fig. 6.2). It was found that articulated whistling is well adapted to communication in such conditions because the characteristic modulations of whistled speech still clearly emerge from the noise.

Background noise that is loud, near the receiver and similar to the signal creates greater problems than noise that is quiet, distant and dissimilar (Bradbury and Vehrencamp 1998). In the former case, the noise may be called a foreground noise.

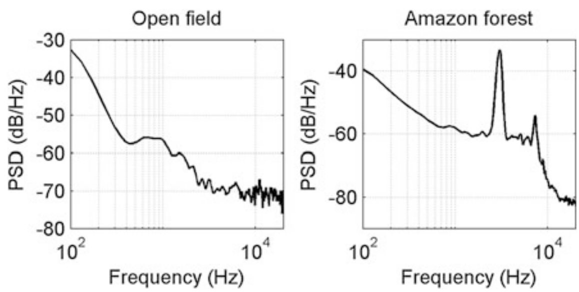


Fig. 6.1 Long term spectrum of a typical *natural quiet* background noise (*left*), and long term spectrum of the background noise in the Amazonian forest (Park of Gunma near Belém, Brazil) (*right*)

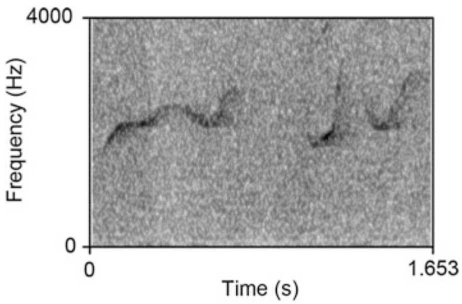


Fig. 6.2 Whistled Turkish signal in the broadband noise of a river. The recording was made at 30 m from the whistler with the microphone near the interlocutor on the other side of the river

The types of natural foreground noises that may interfere most with whistled communications are animal acoustic communications and the acoustic effects of wind. Some species of birds, anurans, insects and mammals produce songs that use the same bands of frequencies as human whistles. Arthropods tend to produce sounds in the 3–10 kHz range. They generally produce signals with regular patterns that are often quasi-stationary and sometimes in chorus. They can be very annoying for human speech communication. For example, we found that in the Amazon forest, some very current species are nearly omnipresent and produce long-lasting frequency bands in the 2.5–3.5 kHz range during the day, masking important acoustic cues of the standard and shouted voice and even of some of the highest frequency bands of whistling (see Figs. 6.1 right, 6.5 and 6.6). Anuran calls may have a wide frequency range and be very disturbing to human communication, but they are much more limited in time and place. Most birds and mammals have vocalizations with frequencies between 1 and 4 kHz (Luther 2008). Calls are generally much shorter than for arthropods and are much less stationary. Therefore, birdsongs and mammal calls may greatly interfere with human voiced and whistled speech but in a different way than that found for arthropods. Most of them consist of the repetition of stereotyped modulated patterns, which allow humans to listen between the gaps and to grasp a part of the masked portion of the signal to cognitively reconstruct the rest, much as they do in speech in noise and in speech-listening tasks (e.g., Hoen et al. 2007; Varnet et al. 2012). Humans also benefit from their ability to focus attention on the dynamics of a specific signal, on the direction of its source and on its distance, which helps the receiver follow a whistled speech signal in such intermittent and frequency-limited foregrounds. For example, when the whistler is surrounded by blackbird songs, as sometimes occurs in some valleys of La Gomera Island, the recognition of whistled speech may require abilities similar to those described by Cherry (1953) in his seminal study on the cocktail party effect. Blackbirds are indeed among the rare animals producing whistled signals with a dynamic that resembles that of human whistles.

6.2 Distance and Sound Propagation

In a natural environment, the impact of the different constituents of background noise on speech is increased by the progressive attenuation of the acoustic signal during its propagation. Spherical spreading is theoretically predicted by the inverse square law of amplitude attenuation. It corresponds to a decrease in intensity of approximately 6 dB for each doubling of distance. However, other factors change the characteristics of the signal during the transmission between two interlocutors, especially through forests (Wiley and Richards 1978, 1982; Blumenrath and Dabelsteen 2004). Absorption associated with multiple scattering by vegetation attenuates sounds and thus reduces the signal-to-noise ratio (Michelsen 1983). Reflection and absorption on the ground may also significantly alter the signal, depending on the topography and the terrain. The duration of silences between sound elements is modified because of sound reverberation that elongates sounds with tails of echoes (Holland et al. 2001) (Figs. 6.3, 6.5 and 6.6). Furthermore, selective frequency filtering, reverberation and atmospheric turbulences distort amplitude and frequency patterns over time, giving recorded sounds a blurred aspect (Wiley and Richards 1982; Dabelsteen et al. 1993). Moreover, atmospheric temperature gradients, which influence the changing celerity of sound in the air, depend on wind and humidity and are difficult to quantify. It is only at night and in rainy weather that these gradients are equalized because in such conditions, there are no air slides. All of these effects profoundly alter the voice, but much less so whistles, as we will see in the next sections.

Some effects of propagation are interesting for signal detection and separation from natural background noise. For example, sounds acquire slow (<50 Hz), large envelope fluctuations during atmospheric propagation because of microturbulence (Richards and Wiley 1980). Such backgrounds can elicit comodulation masking release (CMR) in humans, which is an adaptation of the auditory system for detecting signals over naturally occurring separable backgrounds (Nelken et al. 1999).

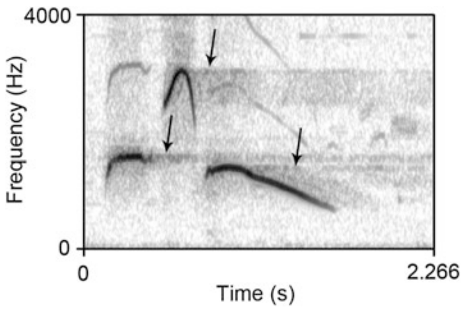


Fig. 6.3 Tails of echoes due to reverberation visible on the whistled Spanish word /amigo/

6.3 Observation of Whistled Speech in Natural Conditions

Some experiments in the acoustic propagation of whistled speech signals have been performed in a deep valley on La Gomera Island and in two types of forest environments—the Amazonian forest in the Park of Gunma near Belém (Brazil) and the forest of Garajonay on the highlands of La Gomera—to observe and measure the effects of the different acoustic constraints in ecologically valid contexts[2] (Fig. 6.4). Preliminary results interesting for the present monograph are presented here.

6.3.1 The Amazonian Forest Soundscape and Filter

6.3.1.1 Design of the Experiment

Lists of Gavião spoken and whistled words (both bilabial and hand whistling techniques) along with Turkish shouted and whistled words were broadcast in the Amazonian forest (Fig. 6.4a). These words were recorded back simultaneously at 6 different distances (1, 4, 8, 12, 16 and 20 m). The background noise was characterized by the presence of natural quiet, some rare episodic birdcalls and the stridulations of one species of arthropods that permanently covered the 2.5–3.5 kHz range with a peak at 3 kHz (see the long-term spectrum of the background noise in Fig. 6.1 right). The overall intensity of background noise was rather stable between 50 and 55 dBA. The mean level of hand-whistled Gavião words was 77 dBA one meter from the loudspeaker (maximum level of 85 dBA). The mean level of whistled Turkish words was 80 dBA (maximum level of 86 dBA). The mean level of spoken Gavião was 55 dBA (maximum level of 65 dBA), whereas the mean level of spoken Turkish was 74.5 dBA (maximum level of 78 dBA). All of the recordings were made in rather stable noise and meteorological conditions (measured on a Geos portable weather station; wind <1 m/s near the recorder, humidity between 80.3–85 %, temperature between 27.9–28.9 °C).

6.3.1.2 Results

The spoken Gavião voice was very rapidly degraded and completely disappeared in the background noise at 16 m (for a reference, the strongest frequency of the word /abía/ was the second harmonic of /í/ and had a signal-to-noise ratio (SNR) of 45 dB at 1 m in its specific frequency bands, see Fig. 6.5). The shouted Turkish voice was also strongly degraded but still showed a reasonable SNR at 20 m, where it

[2] The equipment was adapted to speech transmission: loudspeaker TVM Medium ARM 190–00/8 adapted to faithfully render the voice spectrum (with high response levels between 0.1 and 10 kHz).

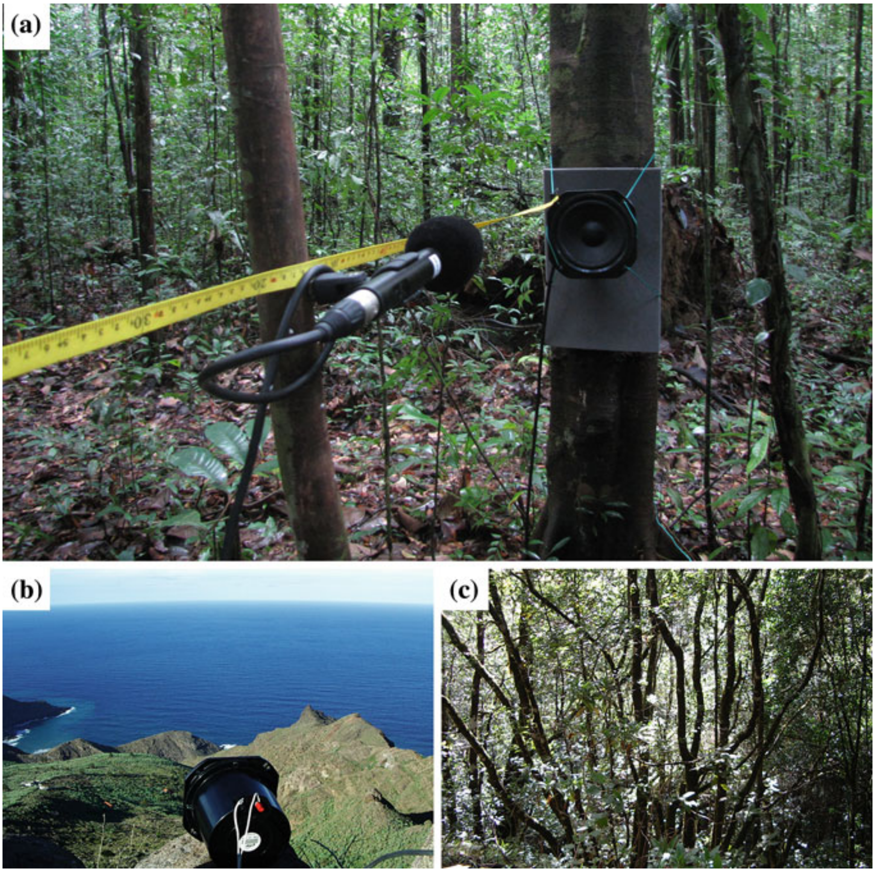


Fig. 6.4 Experimental conditions (environment and/or position of the loudspeaker and/or example of microphone) of the transmission experiments presented in Sect. 6.3. **a** In the Amazon forest (Sect. 6.3.1), **b** In a large valley of La Gomera Island (Sect. 6.3.2), **c** In the Garajonay forest on the top of La Gomera Island (Sect. 6.3.3)

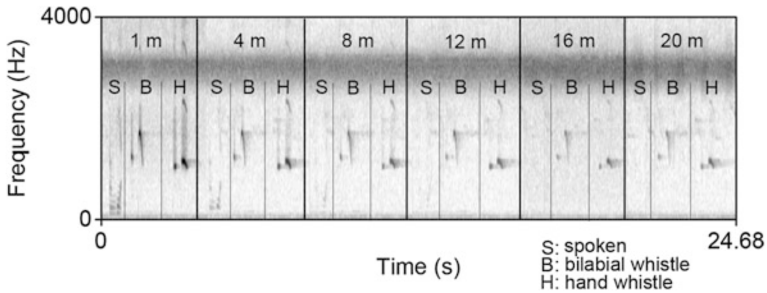


Fig. 6.5 The Gavião word /abía/ in its spoken, bilabial whistled and hand whistled forms recorded back at 1, 4, 8, 12, 16 and 20 m in the Amazon forest (Park of Gunma, near Belém, Brazil)

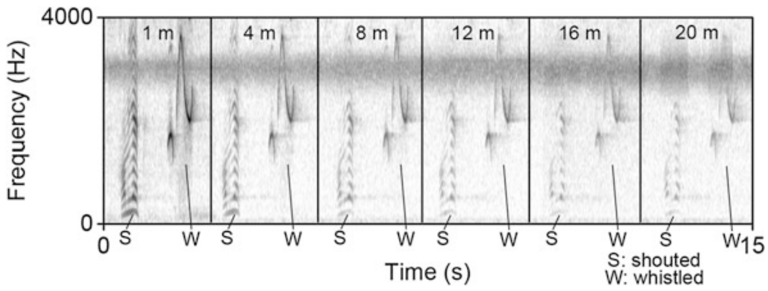


Fig. 6.6 The Turkish word /hamijet/ in its shouted and linguo-dental whistled forms recorded back at 1, 4, 8, 12, 16 and 20 m in the Amazon forest (Park of Gunma, near Belém, Brazil)

remained clear. For example, the strongest frequencies of the word /hamijet/—that is, the third harmonic of the vowel /a/ and the second harmonic of the beginning of the syllable /jet/ as can be seen on Fig. 6.6—still had an SNR of approximately 36 dB at 20 m in their specific frequency bands (versus 58 dB SNR at 1 m and 45 dB SNR at 16 m). Moreover, hand-whistled Gavião was generally stronger and with a narrower range of frequencies than bilabial whistling, but both still had an SNR above 35 dB in the range of whistled frequencies. The acoustic properties of hand whistled signals were characterized by strong energy, a narrow general range of frequencies but a rather large band for each whistled syllable, which explains why they are more suitable than bilabial whistles for long distance communication. Hand whistling remained very clear and powerful at 20 m. Both hand and bilabial whistled forms were in their natural ambience of practice and did not suffer from the arthropods' foreground, whereas the highest frequencies of whistled Turkish were partly masked by the insects' noise, even if they were as strong in intensity as Gavião hand whistling. The last important information to note is that the harmonics of the whistles were rapidly degraded and did not resist propagation well confirming that they do not play an important role for the receiver.

6.3.2 Propagation of Whistled Turkish Consonants in a Large, Deep Valley of La Gomera Island

6.3.2.1 Design

Signals of whistled /ata/, /aja/ and /aka/ utterances cut from real whistled words of Turkish were broadcast with the same loudspeaker as in Sect. 6.3.1. The mean level of maximum frequencies of the utterances was set at 95 dBA to match the real conditions of long-distance whistling with the linguo-dental technique at which the original words were recorded in the mountainous landscape of Kusköy. These utterances were recorded back at four distances (140, 280, 560 and 750 m). The loudspeaker was situated in the middle of the valley in the direction of the slope

(Fig. 6.4b). A skilled whistler verified that the recorded consonants were still identifiable until at least 750 m. The experiment was also performed at 900 m where most of them were very hard to identify due to very strong degradation of the signal. All recordings were made in rather stable noise and meteorological conditions (measured on a Geos portable weather station; wind <1 m/s near the recorder, humidity between 50–55 %, temperature between 15–18.4 °C).

6.3.2.2 Results

Very little reverberation affects the signals. On some recordings, we find that the signal was slightly blurred, most likely because of local atmospheric disturbances during the transmission. We observe that the differences between these three types of consonants are maintained up to 750 m. /ata/ is characterized by a clear, rapid acoustic closure (in 23 ms in the example given in Fig. 6.7a) and by intervocalic modulations above the vowel frequencies. For /aja/, the frequencies of the consonant transitions are also above those of the vowels, but the consonants show a more gradual intensity decrease in intervocalic position that remains observable at 750 m (in 40 ms in the example of Fig. 6.7b). Moreover, the duration of the complete closure of the /t/ remains much higher than that of the /y/. For /aka/, there is hardly any modulation, and the consonants have a clear-cut characteristic of a very rapid closure of the /k/ (in 13 ms in the example of Fig. 6.7c). The vowel and consonant amplitude maxima at 750 m show SNRs in the range of 15–35 dB in the band of whistled frequencies, which is enough to perceive all of the vowel-consonant-vowel (VCV) syllable cues. We also see that the harmonics of whistling disappear rapidly with distance attenuation and therefore, the only useful frequency band is that of the fundamental frequency of whistles.

6.3.3 Interference of the Forest with Akha Whistled Leaf Signals

6.3.3.1 Principle and Design of the Experiment

To verify realistic conditions of use and obtain controlled experimental data on the effect of propagation in the forest on the whistled leaf signal, we designed an acoustic transmission protocol. This protocol consisted of broadcasting (for the purpose of recording back) a short list of syllables in a forest environment (4 sentences containing in total 47 syllables).[3] The experimental context reproduced the real communication conditions observed during fieldwork in Thaïland (Fig. 6.4c).

[3] This approach was employed to control the pronunciation variability inherent to the repetition of the same sentence by the same speaker.

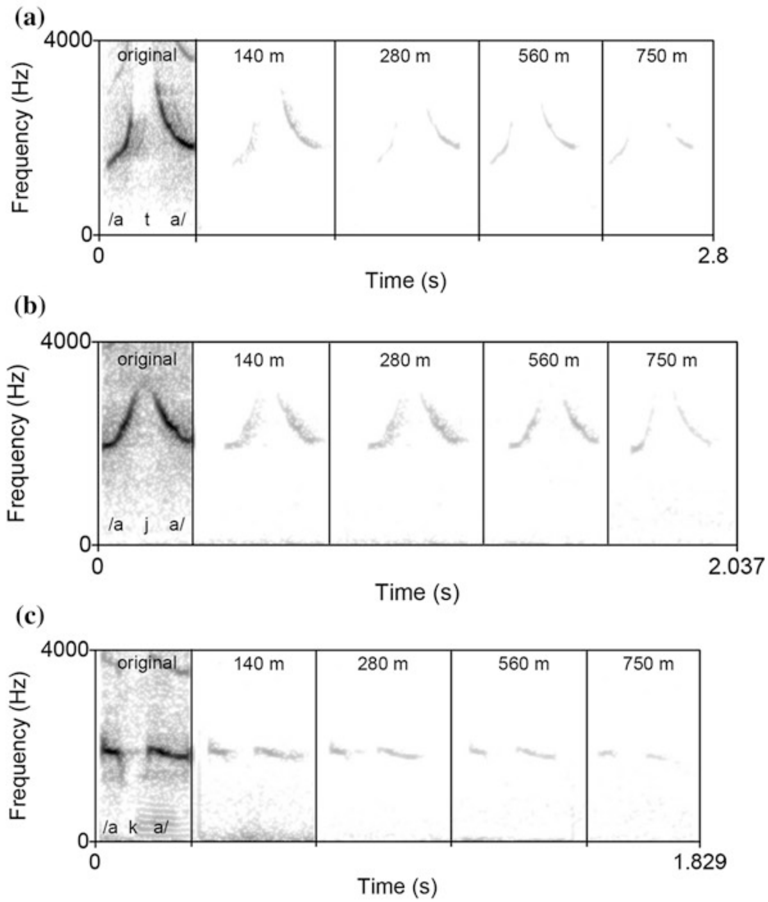


Fig. 6.7 **a** Spectrogram of a /ata/ whistled utterance in its original form and recorded back after transmission at 140, 280, 560 and 750 m, **b** Spectrogram of a /aja/ whistled utterance in its original form and recorded back at the same distances, **c** Spectrogram of a /aka/ whistled utterance in its original form and recorded at the same distances

The experiment was conducted under forest cover without mechanical noise and in relatively stable noise and meteorological conditions (measured on a Geos portable weather station; wind <1 m/s near the recorder, humidity of 60 %, temperature between 16.4–17 °C). We chose the Garajonay forest situated at an altitude of 900 m on the island of La Gomera in the Canary Islands because its properties are similar to those of the forests inhabited by the Akha people around Chiang Rai. We mounted an acoustic chain to broadcast the sounds, which were produced at the equivalent levels of the real production by whistlers [maxima of approximately 100 dB(A)]. The background noise measured in real time throughout the experiment was between 42–48 dB(A) for frequencies under 300 Hz (10 dB(A) less in the frequency range of whistles). A reference recording was made at one m, and we

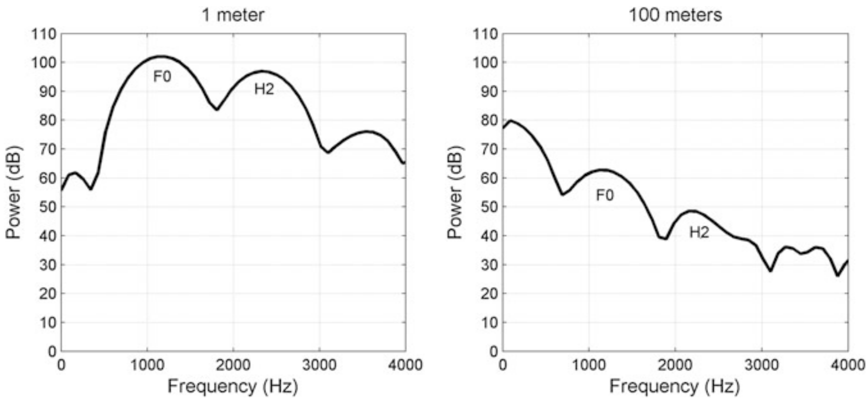


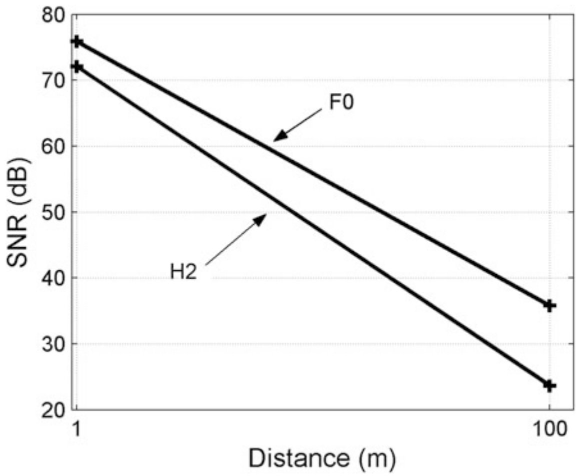
Fig. 6.8 Spectral analysis of the maximum of amplitude of the vowel nucleus of a same whistled word recorded at 1 and 100 m

compared it with the same signals recorded back at 100 m (see the example in Fig. 6.4). The comparison was made at the level of the amplitude maximum of each vocalic nucleus in each syllable. For both distances, we calculated the SNR of the F0 and of its second harmonic (H2) in their frequency range (called local SNR). To enable these calculations, an intermediary step estimating the frequency spectra was developed (examples in Fig. 6.8).

6.3.3.2 Results

The results show that the local SNR diminishes more rapidly for H2 than for F0 (Fig. 6.9), which supports the idea that there might be a differential absorption of

Fig. 6.9 Mean values of the signal to noise ratio at 1 and 100 m for 47 whistled tones of Akha language



the forest in the function of the frequencies. Our data confirm that the F0 values resist vegetation-induced acoustic dispersion well and that F0 is situated within the optimal range of frequencies to communicate as far as possible in this type of biotope. The mean attenuation value of F0 is near the theoretical values when taking into account only attenuation due to distance (40.12 dB, whereas the theory predicts 40 dB). These results are consistent with those obtained with artificial sounds or bird calls in the same bands of frequencies (Wiley and Richards 1982; Mathevon et al. 2005).

6.4 Assets for Long-Distance Communication

The preceding paragraphs and chapters have shown that human whistled signals incorporate several acoustic properties that help compensate for signal distortions and noisy interferences. For example, similarly to normal speech, they include enhanced spectral peaks for vowels, rapid spectral changes for consonants and amplitude modulation patterns to highlight informative portions such as vowel-consonant alternations. They are also the result of an intelligent modification of the voice that enables speakers to increase amplitude, frequency and duration to heighten speech detection and therefore increase whistled speech intelligibility (Meyer 2008) using the same acoustic strategies employed in shouted speech but without the noted disadvantages of shouting (vocal folds quickly tire and reach their biological limit as individuals raise their volume to increase communication distance). Moreover, it is important to note that whistled speech frequencies are also well shielded against acoustic energy loss due to reverberation, which is particularly important in densely vegetated environments. For example, the frequencies belong to the most favorable frequency window—ranging from 1–3 kHz—where reverberation in forests is shown to vary less with distance (Padgham 2004). In mountains, whistlers take advantage of the large open spaces created by valleys because they represent efficient wave guides that ensure good communication. When a signal is blurred by echoes or atmospheric turbulence as it traverses mountains, it remains quite coherent with its original form because of its simple, unique and modulated narrow frequency band carrying information. We also observed that this narrow bandwidth is higher than the most common frequencies of most types of background noise. Whistled signals also resist most of the masking effect of ambient noise and sound attenuation because they are adapted to the most sensitive aspects of human hearing in the time, frequency and intensity domains (static and dynamic). This aspect will be detailed more thoroughly in Chap. 8. As a result, whistled speech overcomes ambient noise at greater distances than normal and shouted speech. Other advantages are that whistles are easy to locate and are unrecognizable to animals or strangers, blending in with natural sounds.

Finally, whistled speech appears to be spectacularly well adapted to the most frequent and pervasive environmental constraints that affect acoustic signals in outdoor rural conditions. They are most likely the best signals that can be produced

by the human vocal tract to convey messages that have good consistency over a distance. Thus, whistled forms of languages represent an adaptation to long-distance acoustic communication in several different natural environments. This idea converges with results from bioacoustics because whistles are also frequently found among the long-distance signals used by non-human animals (Marler 1955). We even found signs of an adaptation of whistled speech to the biotope to which it belongs. For example, whistled signals by Gavião people living in dense forests occupy a frequency range that does not interfere with arthropods' foreground sounds that are frequent in some places. Their productions are also within the frequency window that offers the best resistance to reverberation in forests. In contrast, the highest frequencies of whistled speech produced by the Turkish whistlers living in sparsely forested mountains are partly masked by such insects' noise and are more easily impacted by forest reverberation. The possibility of generalizing this additional level of adaptation of human whistled productions will be discussed in Chap. 9.

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Chapter 7
Phonetics, Phonology and Typology of Whistled Languages

By considerably expanding the range of involved languages, our study not only reveals the significant diversity of the phenomenon but also offers the possibility of tracing its essential typological distinctions and their implications for both speech processing and phonology. In this chapter, we will provide a general sketch of the phonetic and phonological strategies employed by traditional whistlers to transpose their language into whistles. We will also deepen the previous analyses on this subject. Throughout our inquiry, the most notable similarities between otherwise unrelated whistled languages have been observed in a wide range of tonal languages (e.g., Hmong, Akha, Mixtec, Mazatec, Gavião, Suruí, Ewe) and non-tonal languages (e.g., Greek, Turkish, Spanish, Béarnese) which were found to respectively follow either pitch-based or formant-based whistling strategies. These concepts have been introduced in Chap. 2 and they are now described in details. We have selected a large diversity of languages (Greek, Spanish of both La Gomera and Andalusia, Turkish, Chepang, Siberian Yupik, Wayãpi, Tamazight, Gavião and Hmong) to provide a typological overview of whistled forms of languages. We identify a small group of languages that adopt intermediate strategies and where whistlers apparently found a balance between the contribution of pitch and formants to whistled emulations of speech (e.g., Chepang, Siberian Yupik). The systematic comparison of the spoken and whistled forms of speech in various languages enables us to show how pitch-based, formant-based and intermediate whistled transposition strategies adapt to the phonemic inventories of each particular language. We also argue here that the whistled form of a language doesn't define a phonemic system independent from the spoken form in spite of the phonetic reduction at play. Whistled speech recognition is not essentially different from whispered speech recognition or degraded speech recognition.

The original version of this chapter contained errors which have been corrected. These are detailed in the erratum to be found under DOI 10.1007/978-3-662-45837-2_10

J. Meyer, *Whistled Languages*,
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7.1 General Aspects of the Typology of Whistled Languages

The reduction of the frequency space of spoken communications in whistles implies that certain phonetic details present in normal speech are lost. Comparative studies have shown that whistlers choose to prioritize emulation of spoken speech in specific portions of the frequency spectrum of the voice as a function of the phonological structure of their language, that is, as a function of their language's rules of the systematic organization of ordinary spoken sounds. A major distinction in strategy is noted for tonal versus non-tonal languages (Stern 1957; Busnel and Classe 1976; Sebeok and Umiker-Sebeok 1976; Rialland 2005; Meyer 2005, 2008). For most non-tonal languages (e.g., Greek, Karaja, Turkish, Spanish, Wayãpi), in what is called formant-based whistling, whistlers approximate the vocal tract articulation used in spoken form; this approach provokes a whistled adaptation of vowel and consonant qualities carried by the timbre of the voice. For example, whistled vowels are emitted at different pitch levels depending on the frequency distribution of the sonority of their timbre: typically, /i/ has the highest pitch, /e/ is slightly lower, /a/ is still lower and /o/ is the lowest (see, for example, /i/ /e/ /a/ in Fig. 1.1 and the whole vocalic inventories of Greek, Spanish and Turkish in Fig. 7.1). The whistled vocalic space of non-tonal languages is therefore characterized by a frequency scale. In addition, the modulations of these vocalic pitches are found to emulate some aspects of formant consonant transitions of spoken speech (Leroy 1970; Rialland 2005; Meyer 2005) (see, for example, /n/ and /t/ in Fig. 1.1). For tonal languages (such as Gavião or Chinantec, Hmong, Akha, Mixtec, Mazatec, Moba, and Suruí), in what is called pitch-based whistling, the situation is different because the whistles are not focused on emulating the timbre but instead the pitch of the voice, transposing the fundamental frequency of the vibration of the vocal cords to primarily encode the lexical tones. Therefore, in the whistled form of a tonal language, the vowel quality (encoded by timbre) is completely excluded (Cowan 1948; Busnel and Classe 1976; Rialland 2005; Meyer 2008) (Fig. 1.2). This exclusion of timbre in whistled forms of tonal languages occurs even where the functional load of information carried by tones is lower than that carried by vowel quality (Bagemihl 1988).

Finally, just as the distinction between tonal and non tonal languages is sometimes difficult to establish in spoken languages, similarly, there is a category of languages for which the whistlers adopt intermediate strategies between formant-based and pitch-based emulation strategies. Up to now, the few languages that we identified as following this strategy are non tonal where intonation or stress plays an important role in their phonology.

Therefore, the whistled forms of languages display remarkable similarities in terms of the types of sound structures that are represented. Typically, the frequency abridgment at play in whistled languages divides them into typological categories. Interestingly, the acoustic structure of spoken vowels and their mechanism of production appears to explain this typological distinction: spoken vowel production

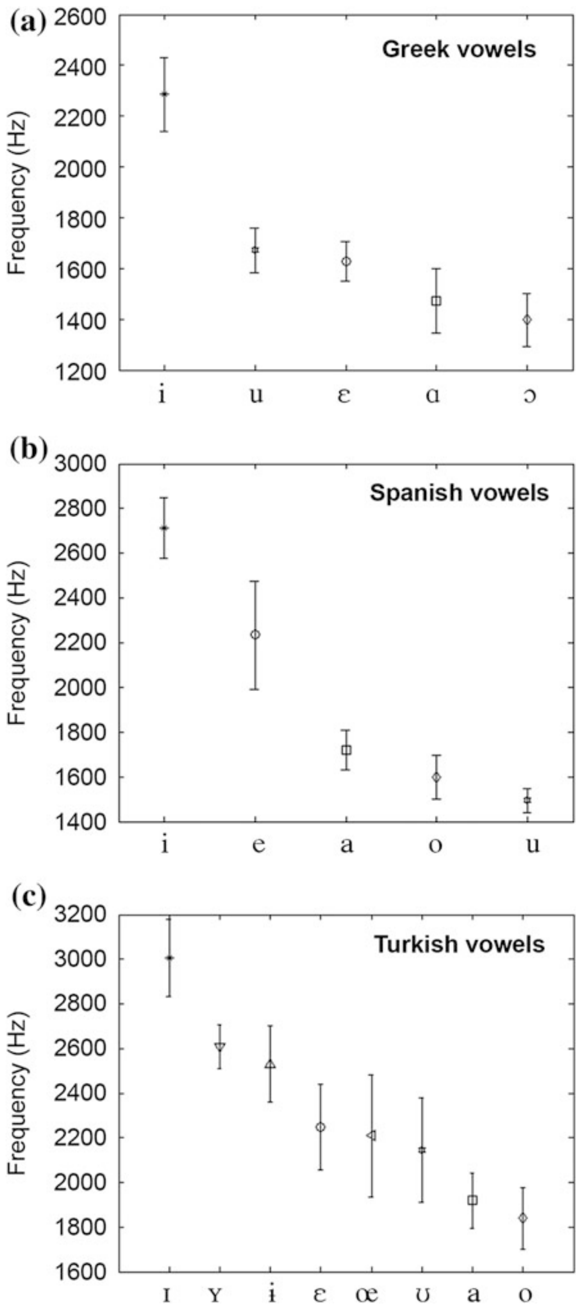

Fig. 7.1 Frequency distribution of whistled vowels (one whistler). **a** Spanish (bent finger technique), **b** Greek (linguo-dental technique), **c** Turkish (linguo-dental technique)

is characterized by both a clear fundamental frequency resulting from the vibration of the vocal folds (called F0 and encoding lexical tone, stress or intonation in languages) and a clear resonant structure from the vocal tract (the formants that

organize the vowel spaces, for example). These two frequency levels are largely independently controllable (Fant 1960), and they can function phonologically as separate channels of information in spoken speech because they are also independently recoverable perceptually through both pitch and timbre (Risset 1968). In this respect, spoken speech contrasts with whistled speech, in which separate control of F0 and resonance is not possible. Indeed, in whistling, the F0 of whistled speech is also the whistled resonance in the vocal tract. In most languages, whistlers solve this dilemma by choosing to emulate only one of the two perceptual attributes carried in normal speech (pitch or timbre) and to adapt it to the phonetics of their language, as we will further describe below.

7.2 The Case of Most Non-tonal Languages, Formant-Based Whistling

Understanding the adaptation of the spoken voice into whistles in this category of languages is one of the most peculiar and instructive aspects of whistled speech. Indeed, it shows how the spoken sonority of timbre and its constituent formant distribution can be reduced into a single whistled stream that transposes vowel and consonant segments. The acoustic resonance of the whistled signal occurs primarily in the front oral cavities of the reduced vocal tract, which correspond approximately to those that play an important role in defining the upper formants of standard speech (above the 1st formant). This situation is why several previous descriptions have noted that whistled speech signals bear frequency shapes similar in several aspects to the 2nd formant of spoken speech, which occupies a central space in the vocal tract (Busnel and Classe 1976; Rialland 2005; Meyer 2008). Classe (1956) is the first to note that the points of articulation targeted by the tongue during the pronunciation of consonants in Silbo Spanish are similar to those of spoken Spanish. He does not provide any graphical, recorded or mathematical proof, but he explains that he was taught to articulate this way by the whistlers who guided his training in whistled speech. Leroy (1970) systematizes this observation on Turkish language of Kusköy by looking for proof in the recordings. She compares and analyzes spectrograms of the whistled and spoken formant transitions. She primarily focuses on noting the link with formant 2, the most central formant resulting from the acoustic resonance in the vocal tract. Such a link is also later noted in Spanish by Brusis (1973) and Busnel and Classe (1976). Rialland (2005) extends these previous works to observe the same phenomenon in detail in Spanish Silbo, and she affirms that only formant 2 is transposed from spoken speech to whistled speech. She finds counterexamples but attributes the observed discrepancies to the fact that *Silbo utterances do not simply copy F2 transitions but involve partly conventionalized patterns* (Rialland 2005: 243).

In the next two sections, we will provide further details on the correspondences between spoken and whistled vocalic/consonantal features. Our work confirms that F2 is effectively a key acoustic cue for the comparison between whistled speech and standard speech. It is most of the time the principal component emulated by

whistling, However, there is some evidence that it is not always the only one. For example, the full description of the mechanism of bilabial whistling production shows that a whistle frequency is always captured by either the second or third formant of the vocal tract and that a frequency jump between the two occurs when these formants are close (Shadle 1983, see chapter 5). This effect is most likely to occur in front vowels and in some consonant transitions. We will provide additional arguments for this when dealing with Turkish vowels (next subsection). Moreover, the constraints specific to whistling and the various factors of variations in whistled frequency shapes that we will illustrate throughout the present section show that there is no need to hypothesize the existence of conventionalized patterns to explain the discrepancies observed between F2 and whistled shapes.

7.2.1 Vowels

7.2.1.1 How Does a Whistled Vocalic System Function?

Whistled systems of vowels follow the same general organization in the non-tonal languages adopting a formant-based whistling strategy. In a previous work, we analyzed the frequency distribution of whistled vowels in various non-tonal languages that were recorded during our field inquiry (Meyer 2008). We found that each vowel position is whistled in a definite frequency interval and that each whistled language has its own characteristic frequency distribution of whistled vowels, which is related to how spoken vowels are articulated in each language (Fig. 7.1). We noted that the values of whistled vowel frequencies may vary according to whistling techniques and speakers' vocal tracts but that their relative distribution does not vary by language. The further the whistlers must communicate, the higher the entire scale of vocalic frequencies, with /i/ remaining below 4 kHz and the lowest vowels—often /o/ —above 0.8 kHz. Therefore, to measure the frequency distribution of vowels, we treated separately different whistlers and different conditions of use (technique, distance). The method we employed to measure the frequencies of each vocalic segment consisted of selecting the value corresponding to the maximum of amplitude of this segment. When there was no clear maximum the measure was taken at the median duration of the segment. In Greek, the five phonological vowels [i, ɛ, ɑ, ɔ, u] are whistled in five intervals in decreasing order of mean frequencies that overlap in unequal proportions so that they statistically define three primary distinct bands of frequencies: (i), (u, ɛ) and (ɑ, ɔ) (Fig. 7.2). The results given here are based on data measured without control of the consonantal context so that they provide the highest variability. We also found that the Spanish spoken vowels [i, e, a, o, u] are whistled in five intervals in decreasing order of mean frequencies, where the values of /o/ and /u/ strongly overlap. Therefore, four groups are significantly different: (i), (e), (a) and (o, u) (Fig. 7.3). Moreover, we showed that the eight Turkish vowels [I, Y, ɨ, ɛ, œ, ʊ, a, o] are whistled in a decreasing order of mean frequencies in eight intervals (I, Y, ɨ, ɛ, œ, ʊ, a, o) that overlap considerably. They also highlight four statistically distinct groups: (I), (Y, ɨ), (ɛ,œ,ʊ), (a, o) (Fig. 7.4).

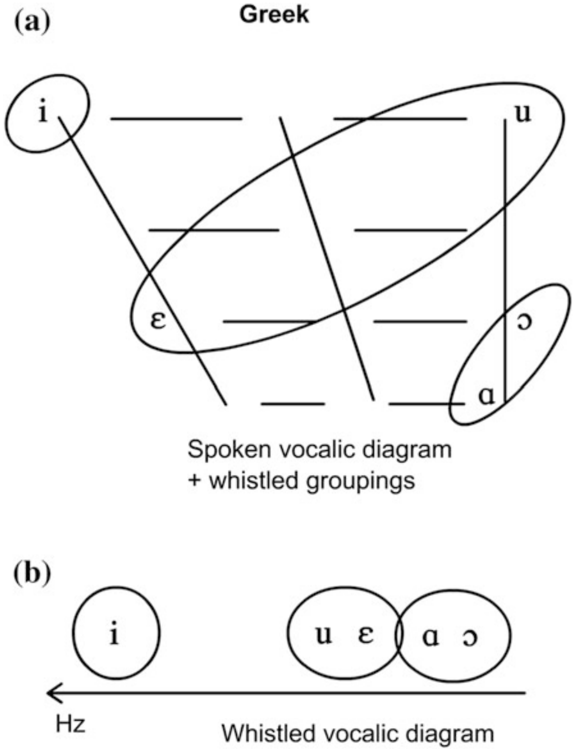

Fig. 7.2 **a** Traditional schematic vowel diagram of spoken Greek where we outlined the whistled vocalic reductions: the *vertical position* on such diagrams denotes the height of the tongue in the mouth when pronouncing the vowel (acoustically corresponding to the vocal tract resonance called formant 1), whereas the *horizontal position* denotes the front/back position of the tongue in the mouth (corresponding to the vocal tract resonance called formant 2). **b** Schematic representation of whistled Greek vowel frequency distribution

The three language-specific frequency scales described above definitely attest that some phonetic vocalic reductions exist in whistles. In this respect, one important question is whether the whistlers mentally assimilate the whistled vowels of the same statistical group (or, said differently, whether we should attribute a phonological value to these whistled phonetic reductions). To answer this question, we must note that traditional whistlers all attest that they try to articulate words while thinking of them as they are normally spoken. This evidence suggests that they never switch to a different phonological pronunciation. In fact, some articulatory cues confirm this. For example, the rounded vowels are still produced with a slight rounding movement of the lips; not enough to produce an acoustic effect on the whistled signal, however, because the lips are kept very tight to produce a strong whistle. We will see other examples regarding consonants later in this paper.

If the whistled vocalic reductions are purely phonetic, as we have just suggested, there are some cross-language differences in vowel reductions that must be clarified. First, the case of the vowel /u/ merits a detailed analysis because of its odd whistled behavior across languages. Indeed, it is either whistled with a rather low frequency, similarly to the vowel /o/ in Spanish, or with a rather high frequency, similarly to the vowel /e/ in Greek and Turkish. In reality, this behavior is partly explained by the fact that [u] is very often pronounced as an [o] in the Spanish dialect spoken on

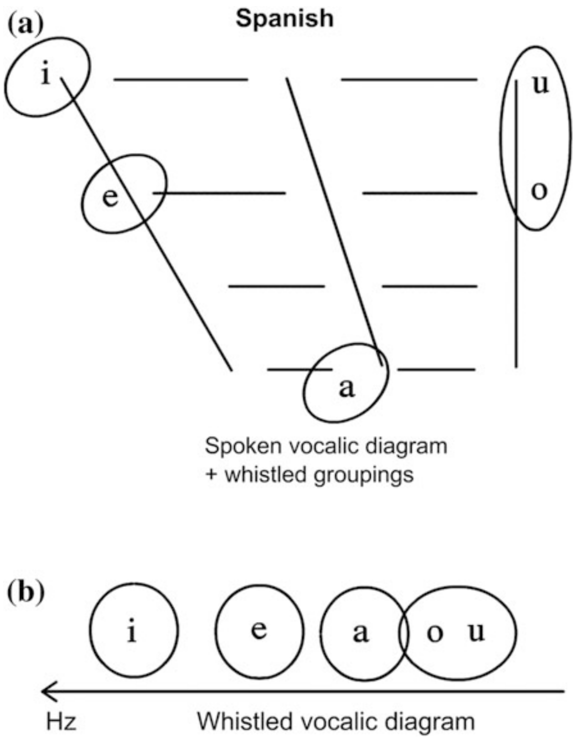

Fig. 7.3 **a** Traditional schematic vowel diagram of spoken Spanish where we outlined the whistled vocalic reductions. **b** Schematic representation of whistled Spanish vowel frequency distribution

La Gomera Island (Classe 1957), which means that whistling only exaggerates a tendency already at play in the spoken form. In contrast, in both Greek and Turkish, the spoken and whistled forms of vowel [u] are clearly distinguished from those of [o]. In Turkish, [u] is the unrounded form [ʊ], with a 2nd formant much higher in frequency than in a standard rounded [u] (1,200–1,500 Hz for [ʊ]). In whistled Greek, the rounding of the spoken [u] is also lost and with the same acoustic effect, but this time due to tight lips while whistling. Because the 2nd formant was found to be one of the principal acoustic cues influencing the whistled emulations of central and back vowels, these additional precisions clarify the special case of [u].

Now, if we look at the Spanish and Greek whistled vocalic systems only (Figs. 7.1a, b, 7.2 and 7.3), we can even hypothesize that the 2nd formant is most likely the only transposed feature, as Rialland proposed. However, this view does not match some of the phonetic reductions observed in Turkish whistled vowels. Indeed, if the 2nd formant had been the sole emulated feature, the Turkish [ɨ] would have been whistled similarly to an [a], and [Y] would have been whistled similarly to an [ɛ] (Fig. 7.4), but this is not the case. This observation indicates that whistlers are influenced by other acoustic cues to emulate vowels. When looking only at what happens in the spoken voice, good candidates for these complementary acoustic cues are the formants that are not visible in the classical representation of vocalic triangles—such as the 3rd and 4th formants—because a whistled-like articulation

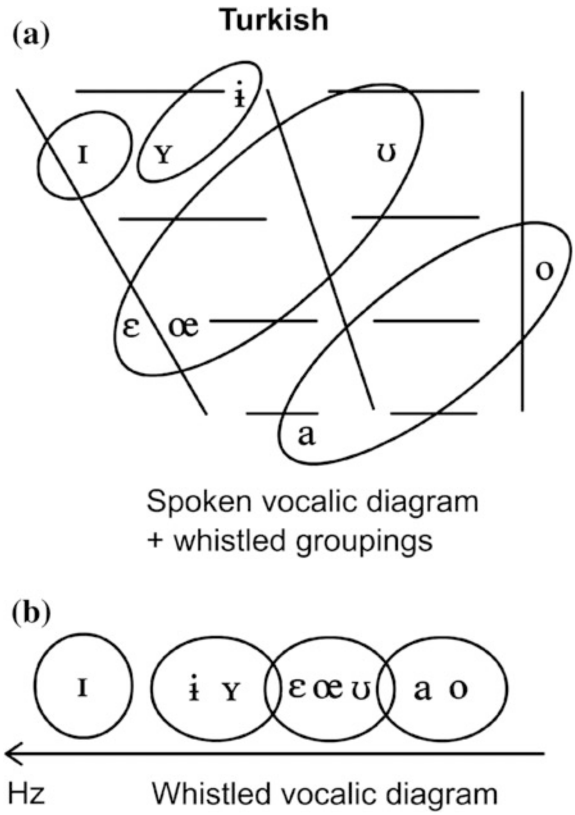

Fig. 7.4 **a** Traditional schematic vowel diagram of spoken Turkish where we outlined the whistled vocalic reductions, **b** Schematic representation of whistled Turkish vowel frequency distribution

reinforces upper formants due to tensed muscles and to a closed position of the vocal tract. This situation is particularly relevant for front vowels—such as [Y] and [ɨ] in Turkish—because several studies on spoken vowels have shown that their 2nd, 3rd and 4th formants are fairly close (Stevens 1998; Schwartz and Escudier 1989). This observation converges with the findings of Shadle (1983) on whistling production because she finds that in such cases, the whistle primarily captures the resonance frequency of F3.

Interestingly, the frequency proximity of formants favors their integration into a unique perceptual entity, providing a perceptual validation of the mechanisms that we just exposed to explain the whistled vocalic reductions observed in Greek, Spanish and Turkish. More generally, the perceptual integration of close formants shows that the perception of whistled vowels is rooted in how spoken vowels are perceived. The perceptual merging phenomenon of two or three close-enough formants was found to occur typically below a critical distance of 3.5 Bark for vowels (Chistovitch and Lublinskaya 1979; Feth et al. 2006); this phenomenon is called the "Center of Gravity" effect (CG or COG). This effect plays an important role in vowel identification (e.g., Schwartz and Escudier 1989). This phenomenon also explains why vowels of different spectra can be matched with the same vowel

quality (Fox et al. 2011). Therefore, whistled forms of languages highlight underlying processes already at play in spoken speech perception and that take a crucial place in whistled speech. As we will see in Chap. 8, there is some evidence that speakers of normal spoken speech are already familiar with the distribution of vowel positions in a simple frequency scale such as the ones found in Greek, Spanish and Turkish. Indeed, we found that naïve French listeners knowing nothing of whistled speech are able to categorize whistled Spanish vowels as whistlers do (see Sect. 8.3.1 and Meyer 2008).

7.2.1.2 Other Aspects of Whistled Vowels

There are other interesting phenomena in vowel whistling that should be highlighted. For example, when the final and initial vowels of two consecutive words are identical, they are nearly always whistled as a single vowel (for example, in Fig. 1.1, /ine eˈ daksi/ is whistled /ine ˈdaksi/). In fact, exactly as in spoken speech, word-by-word segmentation is not always respected, even if two words present two different vowels as consecutive sounds. In the Spanish sentence "Tiene que ir", the /e i/ from "que ir" is whistled as a diphthong similarly to the /i.e./ of the word /tiene/. Additionally, diphthongs are treated as pairs of vowels, that is, a modulation transitioning from the frequency of the first vowel to the frequency of the second vowel.

Another important question is how stress is rendered in formant-based whistling. In languages like Turkish, Greek or Spanish, stress only slightly influences whistled frequencies and is therefore a secondary whistled feature. When it affects frequency, it is expressed by a combined effect of amplitude and frequency increase. However, it does not change the level-distribution of the vocalic frequency intervals. A stressed vowel is often in the highest part of its typical interval of frequency (Meyer 2008). But this is not always the case, as the frequency variation of a stressed vowel in connected speech depends on the whistled frequency of the preceding vowel as shown by Meyer (2005). Finally, the effect of stress on whistled frequencies of Greek, Spanish and Turkish is often overridden by the effects of Consonant-Vowel co-articulation.

One additional interesting aspect of the Turkish whistled vocalic system illustrates how whistled speech adapts to some other complex phonological rules of the vocalic system, such as vowel harmony. Indeed, we have shown that in Turkish the whistled system and the rules of vowel harmony are combined logically and naturally (see Meyer 2008). They provide a simplified space of possibilities enabling speakers to identify vowels with a reduced number of variables. Very few opportunities for confusion exist.

7.2.1.3 Conclusion for Vowels

Through these analyzes of whistled vowels, the simple frequency band of whistles appears to be a significant scientific object relevant to deepen our understanding of

phonetics and phonology. It enables us to complement the studies based on the analysis of complex voice spectra (where the formants are diffuse). We will apply this approach to the frequency and amplitude modulations of whistled consonants.

7.2.2 Consonants

7.2.2.1 General Description of Some Whistled Consonantal Systems

The whistled systems of consonants also follow the same general organization in all of the non-tonal languages, again with some language-specific differences. Consonants are whistled by performing frequency and amplitude modulations of the vocalic frequencies that surround them. When the amplitude modulation shuts off the whistle to emulate rapid amplitude modulations of standard speech, whistled consonants are also characterized by silent gaps. Typically, the whistled frequency shapes of consonants often resemble the frequency shapes of the formant transitions of the 2nd formant and/or the 3rd formant (for the place of articulation), and they encode most of the signal amplitude envelope (for the manner of articulation) (Classe 1957; Leroy 1970; Meyer 2005, 2008; Rialland 2005). In whistling, phonetic consonantal reductions were observed between consonants with close manner and/or place of articulation. For example, the consonant system [p, β, t, ð, k, ɣ, f, s, χ, m, n, ɲ, l, r, j] of the Spanish of La Gomera was found by Rialland (2005) to be reduced to eight different whistled groups of consonants (p, k, f, χ), (t, s), (β, ɣ), (ð, z, l), (j, r), (m), (n), (ɲ), whereas a simplified consonant system of Turkish [p, b, t, d, k, g, v, s, z, ʃ, ʒ, m, n, l, r] consonants[1] was found to be reduced in whistles to the ten following whistled groups: (p), (t), (k), (s, ʃ), (b, m), (d, n), (g), (z, ʒ), (v), (r, l). In Greek, we found that the consonant system [p, t, k, v, θ, ð, s, z, x, ɣ, m, n, l, r] is reduced to the following seven whistled groups: (p), (t, θ, s), (k), (ð, n, x, z), (ɣ), (m, f, v), (r, l). It must be noted here that the precision that is attained in whistling to render consonants is partly dependent on the whistling technique that is employed by the whistlers. In La Gomera Island, the most widespread technique is the bent index finger which leaves less possibilities to articulate labials than the linguo-dental technique that is the most commonly used in Kusköy (Turkey) and in Antia (Greece) (see Fig. 5.12 for a labial closure while whistling a /p/ with this technique). Another factor influencing the precision of realization of the consonants is the proficiency of the whistlers, which is very disparate in situations of whistled speech endangerment. Generally speaking, in any case, both the simple whistled signal and the constraints of articulation due to whistling contribute to enhance drastically the phonetic similarities of consonants already at play in the spoken form.

[1] Excluding palatalized consonants, as well as [f, h, j] and the affricates that are not studied by Leroy.

7.2.2.2 An Insight into Subtleties of Whistled Consonants

To illustrate the similarities between whistled consonants highlighted in the preceding paragraph, we will principally use examples from the Greek language because its consonantal system has not been described yet. When necessary, we will also present results from Spanish and Turkish. In these three languages, two clear distinctions appear among the consonants: one between continuous and non-continuous whistled consonants[2] and one between consonants with high or low whistled loci. The continuous whistled consonants are the liquids (see /r/ in Fig. 7.5 and /l/ in Figs. 7.6 and 7.7), the approximants /j/ and /w/, the pseudo fricative /h/ (which appears only in Turkish and has not been included in any description so far, see Fig. 7.8) and sometimes, /n/. In previous studies (Meyer 2005; Rialland 2005), the fricative sounds of dental and labial fricatives are not found to be whistled at all, and they are categorized as non-continuous (we confirmed this for Greek: see, for example, /s/, /v/, Fig. 7.8). However, we found that this also depends on the rate of speech: in rapid whistled speech, such fricatives may recover their continuous aspect (Fig. 7.9). Concerning loci, consonants with high whistled loci almost always correspond to rising whistled transitions of the frequency of the vowel preceding the consonant and to subsequent falling transition towards the frequency of the vowel following the consonant, transitions,[3] whereas consonants with low whistled loci correspond systematically to falling (before consonant)—rising (after consonant) transitions. The values of the consonant loci of spoken speech may be modified in whistling due to different articulation constraints and a different nature of the signal that is resonating in the reduced vocal tract. In Spanish, Rialland (2005) finds two high loci corresponding to rising transitions (an extra high for sibilants and affricates and a high for other dentals). She also identifies three high loci in Turkish by building on the description of Leroy (1970) and on the perceptual tests of Moles (1970) (mid-high for velars, high for dentals and extra high for sibilants and affricates). With respect to Greek, we first found one unique high locus for all dentals (see, for example, [θ, t], Fig. 7.6). However, in rapid whistled speech, we noted that the loci of the dentals that are continuous in slow whistled speech are often lowered to a mid, whereas the loci of the dentals that are non-continuous are not lowered (Fig. 7.10). Conversely, we found mid-high loci for velars [k, ɣ] associated with [i, ɛ], whereas low loci were found for velars associated with [u, ɑ, ɔ] (Fig. 7.9). This result differs from the velars as whistled in Turkish (mid-high loci for all vowels) and Spanish (low loci for all vowels) (Meyer 2005; Rialland 2005). For Greek labials, we found a unique low locus (see [m] in Fig. 7.5), which corresponds to what happens in whistled Spanish and Turkish labials. With respect to the manner of articulation, a

[2] When looking at intervocalic positions.

[3] In some rare cases, the high locus can be associated with a falling-rising transition pair transition when a dental consonant is coarticulated with /i/ and when the whistler is whistling strongly enough to cover a great distance (see the example of [si] of [ɛðaksi] in Fig. 1.1). Here, the vowel /i/, which is always high in frequency, is whistled extra high due to a special effort and the amplitude-frequency coupling in whistles.

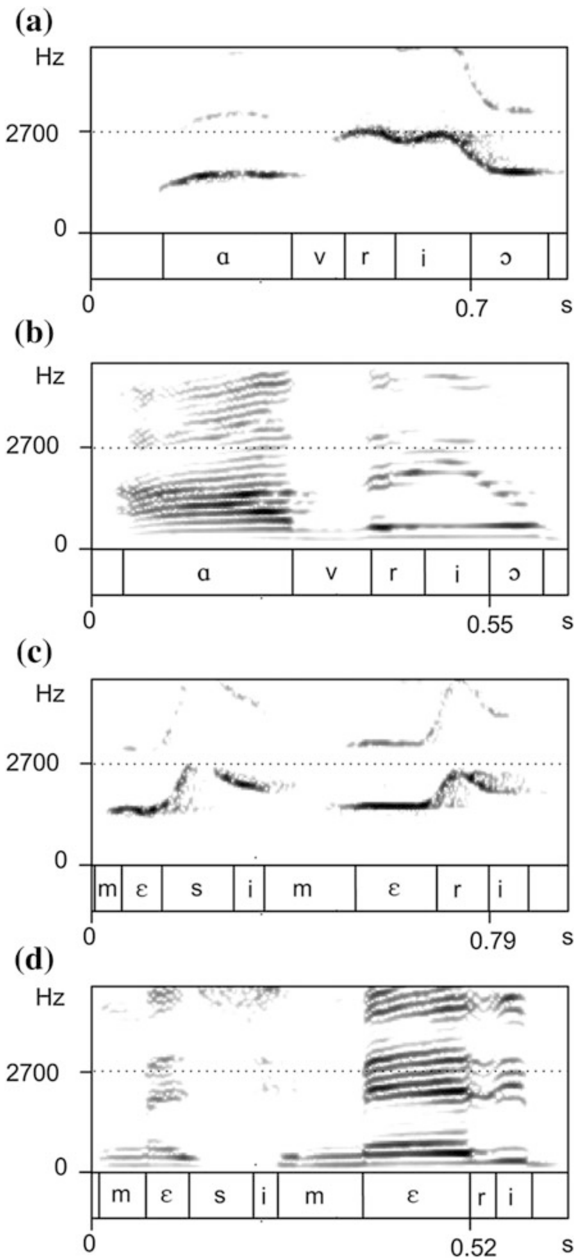

Fig. 7.5 Spectrogram of the whistled (**a**, **c**) and spoken (**b**, **d**) Greek words ‘μεσημέρι’ [mɛsimɛri] (meaning ‘*midday*’) and ‘αύριο’ [ɑvriɔ] (meaning ‘*tomorrow*’)

distinction between voiced and unvoiced stops was formerly identified in Spanish and Turkish (Rialland 2005): voiced stops manifest generally in whistling with a more gradual decay in the signal and/or a shorter complete consonant closure than unvoiced stops. These distinctions also exist in Greek ([ð] versus [t], for example).

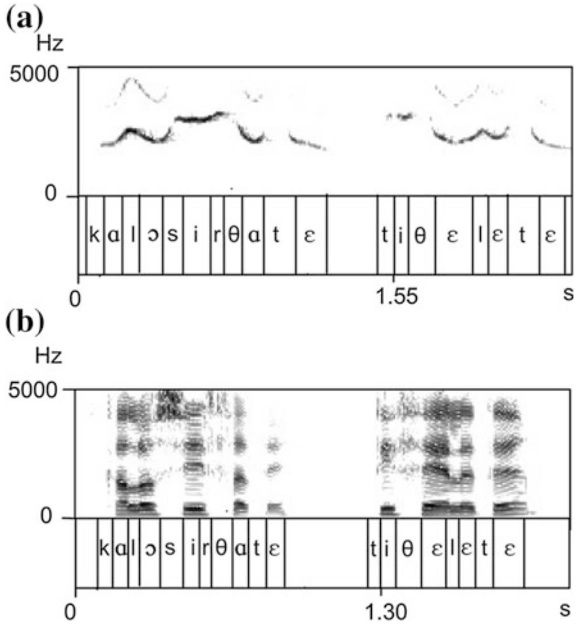

Fig. 7.6 Spectrogram of the whistled **a** and spoken **b** Greek sentence 'Καλώς ήρθατε, τι θέλετε' [kɑlɔs irθɑtε ti θεlεtε] (meaning 'you are welcome, what do you want')

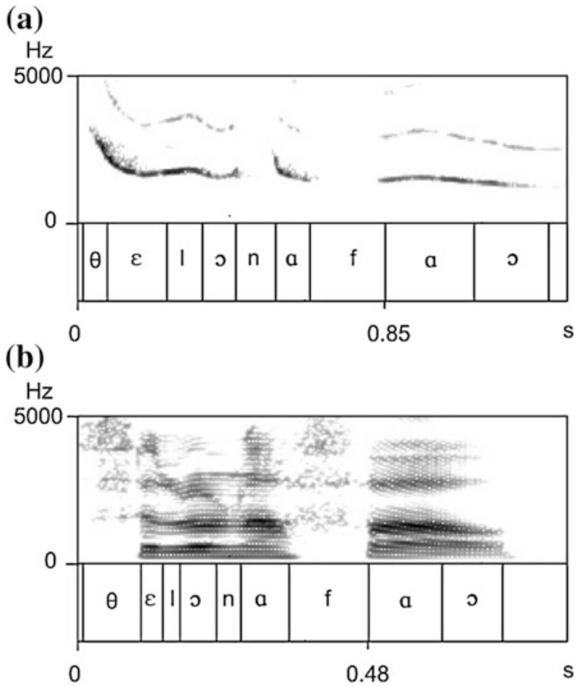

Fig. 7.7 Spectrogram of the whistled **a** and spoken **b** Greek sentence 'θέλω να φάω' [θεlo nɑ fɑɔ] (meaning '*I want to eat*')

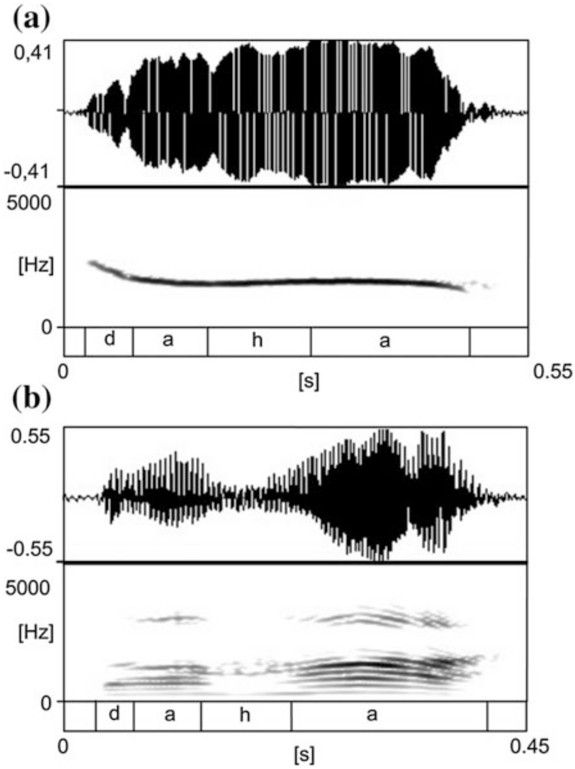

Fig. 7.8 Spectrogram of the whistled **a** and spoken **b** Turkish word 'daha' [daha] (meaning '*more*')

Moreover, we found that the gradual decay also characterizes Greek labial fricatives such as /f/ and /v/ along with nasals (see /f, n /in Fig. 7.7, /v, m/in Fig. 7.5).

As explained earlier, the groups of phonetic consonantal reductions would have been slightly different if we had considered a quicker rate of whistled speech. In this respect, the difference between dental stops and dental sibilants in rapid whistled speech shows that the whistlers do intend to articulate them differently, even if they are difficult to distinguish on spectrograms at a slower rate. Another interesting and ecologically valid approach is to consider the signals at the level of the receiver, when he is quite far from the emitter, as we did in Chap. 6. We see for example in the Fig. 6.7 that what is important in the distinction between /j/ and /t/ is not the continuous-interrupted distinction, but rather the duration of the closure and perhaps the dynamics of the slope of the modulation.

7.2.3 *Recently Documented Languages Belonging to This Category*

Spanish of Topares uttered with the traditional whistle called pito that plays the role of an 'artificial whistling palate' (Figs. 3.6 and 5.10), but also Tamazight

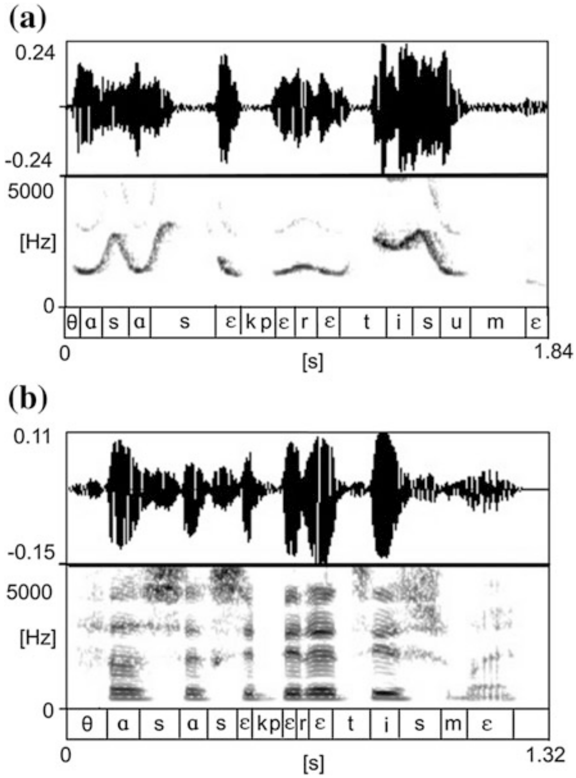

Fig. 7.9 Spectrogram of the whistled **a** and spoken **b** Greek sentence 'θα σας εξυπηρετήσουμε' [θɑ sɑs ɛkspirɛtisumɛ] (meaning '*at your service*'). The rate of speech explains some elisions (the [u] in spoken speech; the [s] in the [ksp] cluster in whistled and spoken speech) and some assimilations, such as the one of [ir ɛ] to [ɛ] in [spi]

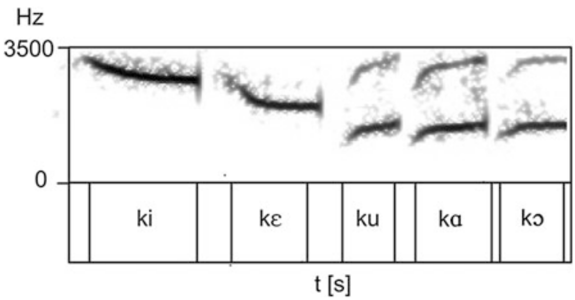

Fig. 7.10 Example of whistled modulations towards the articulation locus of the velar Greek consonant [k] as a function of the vowel. Cross-linguistic differences were found for the articulation loci of velars, partly due to the use of different techniques of whistling in each region (linguo-dental constriction of the air in Greek of Antia and Turkish of Kusköy, bent finger inserted in the mouth in Spanish of La Gomera)

(Figs. 3.8 and 5.2) and Wayãpi (Fig. 3.11) are the latest documented non tonal languages that belong to the formant based whistling category. We will just present here some examples of these languages showing that they clearly adopt a whistled strategy of transposition that is similar to the one of Silbo, Greek or Turkish.

7.2.3.1 Whistled Spanish in Andalusia

The two utterances /ostia/ and /un beso/ presented on Fig. 7.11 show that the vowels of Topares whistled Spanish are distributed much like in Silbo of La Gomera (that is, /i, e, a, o/ in a decreasing order of frequencies). We note that /u/ is whistled quite low similarly to what happens for this vowel in La Gomera. Classe (1956, 1957) already mentions that the Spanish dialects of La Gomera and Andalusia are pretty close in pronunciation, with [u] and [o] often confounded, even in the spoken form. Moreover, these examples are also the occasion to illustrate what is going on during a consonant cluster: the consonants are concatenated, just like in standard speech (see also Meyer (2007) and Meyer (2005) for more information on whistled clusters in Turkish, Spanish and Greek). Here, the /s/ and the /t/ form a common closure. We clearly note the distinction between the super high locus of /s/ and the high locus of /t/ in the word /ostia/. However, the locus depends also of the vocalic surroundings of the consonants. For example, the difference of articulation between the /s/ of /ostia/ and the one of /beso/ clearly show a variation due to coarticulation with different vowels and consonants. Finally we note here that the signal is a little blurred, which can be attributed to the fact that the whistler is old (82 years old) and has holes in his denture.

7.2.3.2 Wayãpi

The example we show on Fig. 7.12, illustrates also that /i/ is whistled high in Wayãpi while /a/ is whistled low even when both are nasalized. This particularity is

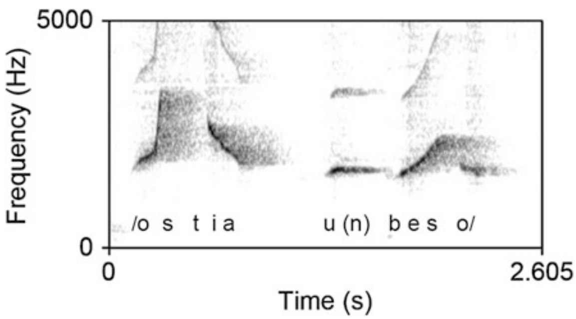

Fig. 7.11 Spanish words [ostia] and [un beso] whistled with the *boca or pito* whistle still found in Topares, Andalusia

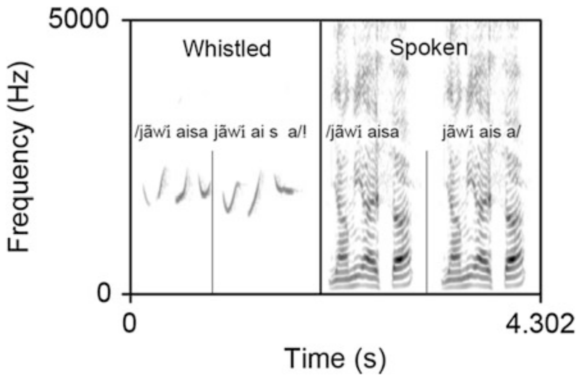

Fig. 7.12 Wayãpi sentence [jãwĩ aisa] (meaning *I found a turtle*) repeated twice in whistled form and in spoken form

the occasion to explain here how the whistled emulation of the spoken voice requires sometimes a slight change in the pronunciation: for example nasal consonants and nasalized voyels are produced by lowering the soft palate without opening the nasal cavity. As can be seen here, the Wayãpi whistlers often repeat rapidly twice the sentences they whistle in order to maximize the chances of being understood clearly in the noisy and reverberant environment of the forest. The recordings were made during a simulation of a hunting session, nearby Camopi village in French Guiana. The celerity of the whistles reflects the need to be quick and efficient to be sure to collect enough food during the journey in the forest, while remaining discreet not to frighten the potential game. This example also provides an illustration of variation of realization of a same sentence. Typically, the /w/ of the first word clearly interrupts the whistle in the first occurrence but is continuous in the repetition. The last vowel of the repetition of /aisa/ is also influenced by the intonation inviting the interlocutor to come rapidly.

7.2.3.3 Tamazight

The sentence [ittʃa aʁrom][4] provided in Fig. 7.13 shows how some of the Tamazight vowels and consonants are whistled. For example the uvular fricative ʁ is a new segment to include in our typological comparison. Moreover, preliminary observations showed that the three underlying vowels /i, a, u/ are quite sensible to prosody at the end of a speech group (here, /u/ is whistled quite high in frequency). Interestingly, Tamazight Berber is a ‘consonantal language’ characterized by a rich system of consonantal phonemes, complex clusters of consonants, an optional schwa-like element and a syllable structure often cited as typologically unique because it allows any segment to be a syllable nucleus (Ridouane 2014). A full study of the recently collected data will surely provide more indication on how the segmental complexity of this language is transposed into whistles, which might

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[4] We thank Dr. Ridouane for help in transcribing our corpus.

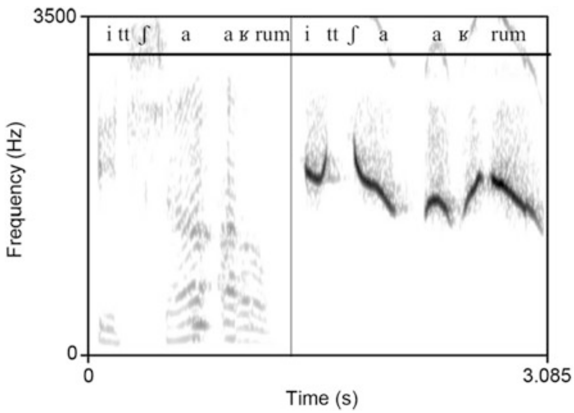

Fig. 7.13 Tamazight sentence [ittʃa aʁrom] (meaning *he has eaten bread*)

give a new insights into Tamazight syllabic structure. Each new whistled language that is discovered increases our knowledge on the possibilities and functioning of this peculiar whistled speech register. It also provides alternative insights into the languages that are expressed this way, with the potential to inspire new research on standard speech.

7.3 The Case of Tonal Languages, Pitch-Based Whistling

In tonal languages, the general situation is simpler because whistles conform principally to lexical tones and therefore, to the variations of the F0 of the spoken words. Tones constitute an independent phonological entity that can be directly expressed by the whistled pitch because tones and whistles share a common, quintessentially prosodic nature favoring a direct association: thus, vowel quality (encoded by timbre) is completely excluded. In tonal languages, the exclusion of timbre occurs even when the functional load of information carried by tones is lower than that carried by vowel quality (Bagemihl 1988), such as in Suruí of Rondônia, which has a simple two-tone system (Guerra 2004). This difference is potentially important for general phonology, suggesting a perceptual precedence of tone over vowel segment for speakers of tonal languages. Whistled speech is unique among natural speech practices in having such a characteristic associated with tonal languages.

This strategy also has the advantage of resolving a potential conflict between F0 and segmental quality in whistles, as has been evidenced for example in one language, Chepang, which has been described as an incipient tonal language (Pike 1970; Caughley 1976). In this language, the whistled vocalic frequency scales resulting from vocal tract resonances remain present because the language is non-tonal. However, this scale is broken under the influence of F0 on central vowels and is partially broken in back vowels (Caughley 1976; Meyer 2005, 2008); see below in Sect. 7.4 where Chepang serves as an example to how such intermediate strategies are analyzed.

In addition to tone, which is rendered by pitch patterns, basic segmental information is rendered by the amplitude envelope of whistled tonal languages. Vowels are more energetic than consonants, and in general, two distinct classes of whistled consonants exist in tonal languages as a function of the continuity of the whistle: a continuous or near continuous signal versus a clearly interrupted signal (in intervocalic position). However, few phonetic studies have detailed these aspects. In Hmong, for example, nasals and voiced laterals are found to be continuous (Meyer 2005; Rialland 2005), whereas all of the other consonants are found to be interrupted when whistled. In Moba, liquids, nasals and glides are found to be continuous or near-continuous whistles, whereas obstruents, either voiced or voiceless, are found to be interrupted whistles (Rialland 2005). Moreover, our data on the Gavião language of Rondônia are consistent with these findings. Indeed, in a set of 16 sentences and 158 words with 658 consonants in intervocalic position (for each of the two traditional whistlers we recorded), liquids, nasals and glides were found to be continuous or near-continuous whistles. These always show a partial closure of the articulators, which explains why they sometimes appear as near-continuous (such as /n/ in the word /ini/ of Fig. 1.2). They contrast with obstruents, which are found to be interrupted whistles (see /t/ of Fig. 1.2, /b/ of Fig. 7.14, /t/ of Fig. 7.15). Therefore, such pitch-based tonal whistles encode the gross frame of amplitude of the spoken signal, in addition to the pitch patterns. We found that other fine temporal aspects resulting from the amplitude envelope were rendered by the duration of consonant closure, and they may help whistlers separate consonants into various classes that are the same as the ones used in spoken speech (Fig. 7.16). For example, voiced consonants are whistled with a shorter closure than voiceless (see and compare /b/ of Fig. 7.14 with /t/ of Fig. 7.15). There were also differences between the purely bilabial whistling mode and the hand whistling modes, mostly concerning palatals and dentals for which we observed clear pitch modulations in bilabial whistling but not in hand whistling (see /t/ in Fig. 7.15).

7.4 Some Rare Languages with Intermediate Strategies

7.4.1 Two Non-Tonal Languages Where Intonation Strongly Influences Whistles

Siberian Yupik and Chepang are two non-tonal languages apparently adopting an intermediate whistled strategy between pitch-based whistling and formant-based whistling. These two languages are representative of a balanced contribution of both formant distribution and prosodic intonation in the whistled transposition. Few languages seem to belong to this intermediate category and the reasons why they adopt such type of strategy is probably due to the important phonological role played by stress and/or intonation in some non tonal languages. For Siberian Yupik, the large consonantal inventory also seems important.

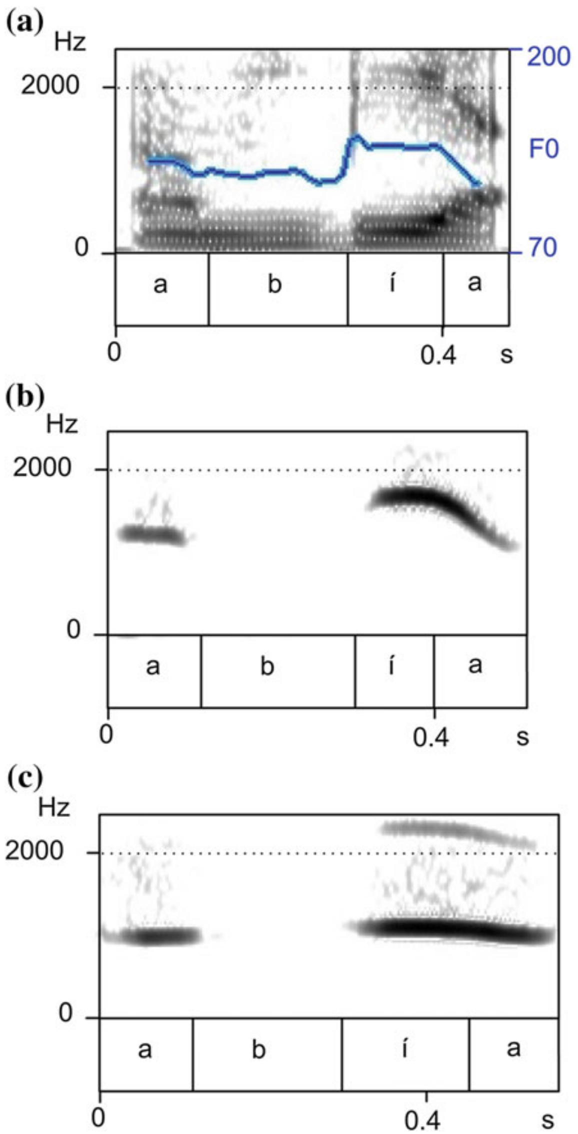

Fig. 7.14 Spectrograms of the Gavião word *abía* [abia] in three modalities. **a** Spoken pitch was extracted in *blue*, **b** bilabial whistling, **c** hand whistling (Reproduced from Moore and Meyer 2014)

Chepang, is a Tibeto Birman language of Nepal that has been analyzed in details both phonemically and phonetically (e.g., Pike 1970; Caughley 1976). It is described as an incipient tonal language. What maintains Chepang among the non tonal languages is the fact that a glottal in final position imprints a falling movement to the spoken prosodic line. This effect is also mirrored in the whistled form by a falling whistled pitch. The analysis of whistled Chepang was principally focused on the analysis of the influence of various phonetic features on the pitch of the vowel

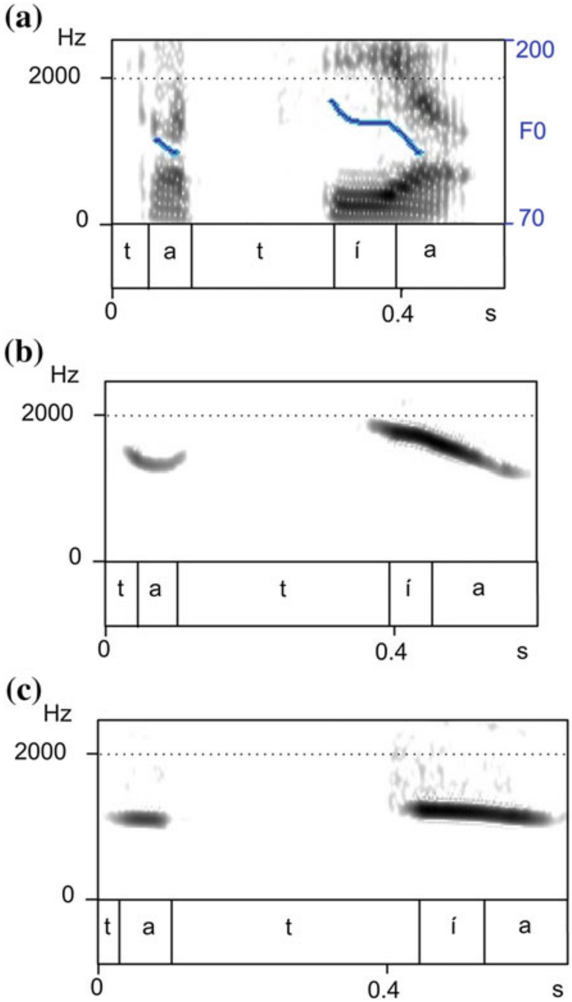

Fig. 7.15 Spectrograms of the Gavião word *tatía* [tatia] in three modalities. **a** Spoken pitch was extracted in *blue*, **b** bilabial whistling, **c** hand whistling (Reproduced from Moore and Meyer 2014)

nucleus (including the quality of the vowel and the coarticulated consonants). We will describe these aspects in the next sections.

For Siberian Yupik, detailed phonemic analyzes of the spoken form have described a complex prosodic system that includes several levels of stress: first, inherent stress on heavy syllables (heavy syllables include long vowels and/or a consonant in coda position); second, iambic rhythmic stress (a syllable following an unstressed one is stressed); third, final syllables loose stress; fourth, rhythmic lengthening rule (concerning CVV syllables and short stressed CV syllables with [i, a, u]) (see Jacobson 1985). The description of a first corpus of whistled Siberian Yupik has shown that whistled /a, e, u/ (/e/ being the schwa) are very variable, and overlap considerably between each other, while /i/ was found statistically different

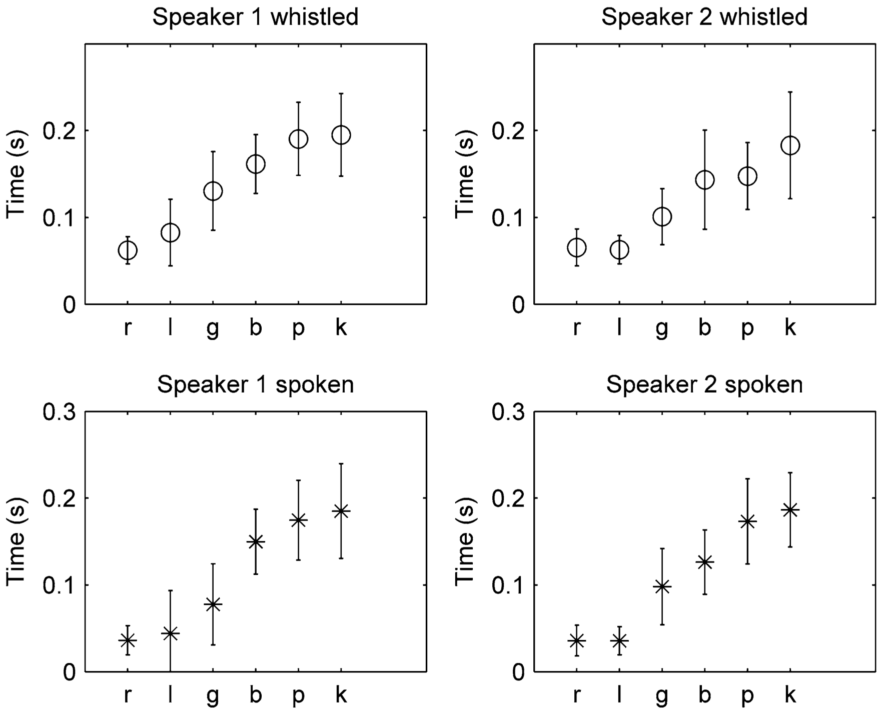

Fig. 7.16 Closure duration in Gavião whistling (bilabial whistling technique, from a sample of 158 Gavião words with 658 consonants in intervocalic position)

(Meyer 2008). However, newly collected data with other whistlers (in bilabial and two-finger whistling techniques) show that there is also large variability on the /i/ for some whistlers. We think that the contribution of each type of stress must be measured separately to enable a better understanding of their respective contribution to the whole system. For consonants, a preliminary approach showed that modulations are very strongly marked just as in formant-based whistling. The large inventory of complex velar and glottal consonants is also of great scientific interest. Figures 7.17 and 7.18 show how some of these consonants are whistled and also offer some illustrations of the impact of prosodic vowel lengthening and prosodic intonation on the whistled transposition.

7.4.2 Additional Details on Whistled Vowels and Consonants

The special methodology developed by Caughley to analyze whistled speech in Chepang is directly inspired by his analysis of the intonation in the spoken form. He observed that pitch is influenced both in spoken intonation and whistled talk by two

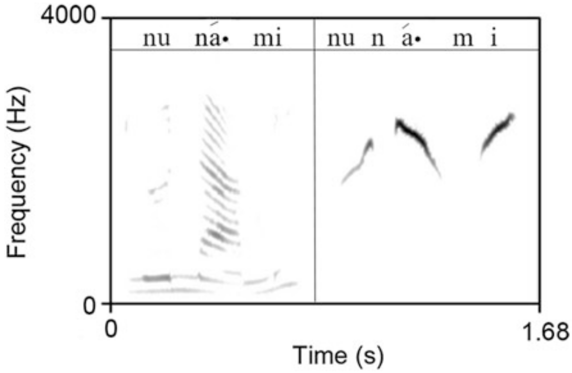

Fig. 7.17 Spoken (left) and Whistled (right) forms of the Siberian Yupik word [nuná•mi] 'on land' [the stressed vowel was written with an acute accent and its prosodically lenghthening was transcribed with [V•] as in Jacobson (1985)]. We note here that the stressed /a/ is as high in frequency as the unstressed /i/

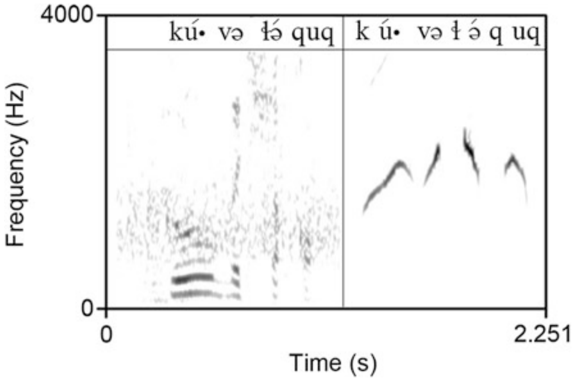

Fig. 7.18 Spoken (left) and whistled (right) forms of the Siberian Yupik word [kú·vəɬə́quq] 'it will spill' [the stressed vowels were transcribed with an acute accent and the prosodic lengthening of the first vowel was transcribed with [V•] as in Jacobson (1985)]. Here, we show two original aspects of Siberian Yupik: the phonemic presence of the schwa as well as the clear difference of duration between short [u] and lengthened [u•]

articulatory criteria of the vowel nucleus affecting its weight: height (high, mid or low) and backness (non-back vs. back). He measured '*generally higher average pitch with the high front vowel /i/, lower with the low back vowel /o/*' (Caughley 1976: 968). Moreover, from the same sample of data, we verified this tendency, showing also that the whistled frequencies of /a/, /u/ /e/ are the most variable (Meyer 2008). Therefore, for vowels in Chepang, the frequency scale resulting from the underlying influence of the formant distribution still shows some evidence of contribution to whistled pitch, but it does not have the systematically dominant influence as in Turkish, Greek or Silbo. Three groups of vowels have been

identified as a function of the influence of the formant distribution on whistled pitch. The first group is formed by /i/ only: its formants 'pull' the frequencies of the vowel quality towards higher values so that /i/ generally remains high in whistled pitch even if, in some configurations this tendency appears to be disturbed by prosodic context. Next, the group formed by the vowels /e, a, u/, which have intermediate frequency values in the whistled scale, is more dependent on prosodic and consonantal contexts. Finally, the group formed by /o/ alone pulls frequencies to lower values but may also be dependent on the prosodic context (Meyer 2008).

One other important phonological distinction present in Chepang is quantity. Long vowels exist only for [a]. We note here that long vowel also exist on Siberian Yupik for [i, a, u]. This aspect is systematically rendered by whistles; long vowels are whistled longer than short ones (Fig. 7.18). This feature also affects the weight of the syllable and was described by Caughley as generally lowering slightly the pitch of whistling in Chepang.

Finally, results of published analyzes on whistled consonants exist only in CHepang and they are still very preliminary. Caughley identified that the more obvious results are the effect of depressing pitch by a velar such as /k/, and raising of it by the grooved fricative /s/. The glottal has a falling effect on pitch as we signalled earlier. The depressing effect of voicing on the whistled pitch is also consistent. Meyer (2005) identified that whistled /t/ and /d/ behave like /s/ and that their modulations sometimes reach the transient present in the recordings made by Caughley. /p/ is a clear interrupted signal, /j/ is whistled continuous.

7.5 Conclusions

Because of constraints inherent to the whistled production, whistled speech simplifies the phonetics of spoken speech but is still based on spoken language phonology. The phonetic features emulated in whistles appear to be due to a hierarchical selection: first, the presence/absence of phonological tones in the language defines which perceptual channel of spoken voice will be emulated in frequency: either pitch or timbre. Next, the elected perceptual channel is emulated as faithfully as possible. As we began to see with Chepang and Siberian Yupik, there are some languages for which the pitch-based/formant-based whistling distinction is not so clear, or for which the complexity of the prosodic system seems to affect so much intonation and therefore blurs the choice of the whistlers between formant-based and pitch-based strategies of whistling. More research is needed on this category to understand which criteria are essential in the choice of the whistlers. The difficulty is to find the rare languages of this category and to find good whistlers in these languages.

However, in the great majority of the languages of the world, the pitch-based/formant-based distinction is clear. We will therefore here draw conclusions for these clear cases. In general, whistlers have no difficulty to emulate completely pitch melodies of spoken voice in tonal languages because they bear a common

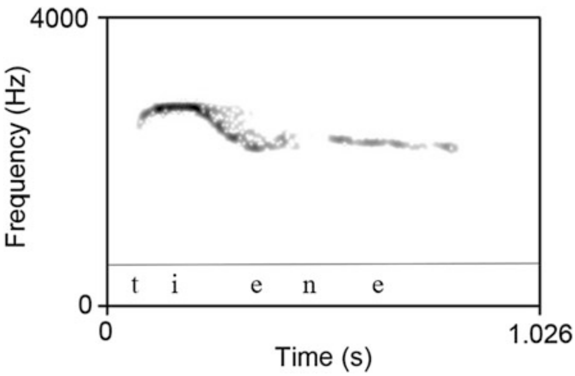

Fig. 7.19 Whistled Spanish word /tiene/ (meaning *there is*) whistled by one maestro of Silbo of la Gomera (Mr. L, who was also informant in Rialland 2005). Here the whistled transition of /t/ associated to /i/ is below the frequency of the vowel whereas it is much more common to find transitions above vowels for a /t/. However, this example proves that for some reasons (position of the finger, strength of the whistle) even this aspect is not conventionalized in whistled speech

prosodic nature with whistles. On the other hand, the whistled imitation of segmental qualities in formant-based whistling of non tonal languages supposes strong phonetic reductions to adapt the standard spoken stream to a whistled stream. We saw that these reductions are still easily associated with the original spoken utterances because they call perceptual processes already at play in spoken voice recognition, such as perceptual integration of close formants. In any case, the degree of precision of the whistled emulation partly depends of the whistling technique chosen by the whistler and partly of the proficiency of the whistler (particularly in contexts of vitality loss where competences are very disparate). There is also some variation due to the rapidity of elocution. In reality, most sources of phonetic variation present in standard speech also are emulated in whistled speech and we didn't find any process of conventionalization when working on recordings made with good whistlers (see one example in Fig. 7.19). In formant based whistling, we confirmed that the whistlers really intend to articulate every vowel and every consonant while whistling. For all these reasons, we argued that there is no need to attribute a specific whistled phonemic value to the whistled reductions found in consonants and vowels of non-tonal languages. Just a in whispering or shouting, the speakers focus on the same phonemic targets as standard speech, but less accurately and with a very different signal. These observations suggest that the problem encountered by the whistlers listening to whistled sentences has more to do with a cognitive restoration of a degraded speech signal than with matching two different whistled and spoken phonemic systems.

For both pitch and formant based strategies whistled speech recognition requires a large amount of cognitive recovering, but of different nature. The recovering is particularly demanding and difficult in the tonal languages, especially in those based on few distinctive phonological tones, because the segmental information is omitted.

This is the reason why whistled speech in Suruí, Gavião or Akha involves a rather limited number of common sentences that are clarified by the context of use. On the other hand, for formant-based whistling, whistled speech produces a different percept of a fully intelligible sentence, despite the elimination of canonical acoustic correlates of phonemes from the spectrum. A portion of this perceptual flexibility can be attributed to center-of-gravity sensitivity and to modulation sensitivity in the auditory-to-phonetic projection. These functions are critical for establishing the perceptual integrity of sound streams. The extraordinary potential of whistled speech to investigate these perceptual effects is highlighted in the Chap. 8.

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Chapter 8
Perception and Neurocognitive Aspects

Whistled speech shows the tremendous capacity of the human brain to recognize speech from reduced acoustic cues and even from signals that are very different from the voice. In this chapter, we focus on explaining why and how a simple modulated melodic line is sufficient for trained whistlers—but not for untrained ones—to achieve a reasonable degree of word and sentence recognition. Therefore, we explore the perceptual and neurocognitive aspects associated with whistled speech. We will see that the processes that enable the comprehension of whistled speech remain little studied despite their capacity to highlight in a targeted way the cognitive properties associated with the perception and recognition of several key parameters of language, such as pitch, speech prosody and speech segments.

First, we will highlight the special adaptation of whistling to human hearing and speech stream perception. Next, we will describe and reinterpret the results of the few seminal studies that have been conducted on whistled speech recognition. For example, Busnel and colleagues have shown that whistled words are recognized at a rate of 70 %, whereas common whistled sentences are recognized at a rate of approximately 90 % (Busnel 1970). We will also see that whistled languages remain almost completely unstudied by modern neuroscience, except for a single study showing that the brain areas associated with language are activated in well-trained listeners (whistlers of Silbo) but not in untrained ones (Carreiras et al. 2005). Other interesting behavioral studies have found that naïve listeners are able to categorize whistled vowels—once they are told that whistles emulate vowels and consonants—in the same way as do whistlers in non-tonal languages, even if the former do so less accurately (Meyer 2008). This evidence shows that the cognitive linguistic representations used to categorize spoken vowels are easily associated with tonal frequencies by native speakers of non-tonal languages. Taken together, such studies open the fascinating possibility of using the natural practice of whistled speech as a model to examine the perception of spoken language, cognitive plasticity, language/non-language differences and the phonological role of the acoustic cues selected for whistles across languages.

The original version of this chapter contained errors which have been corrected. These are detailed in the erratum to be found under DOI 10.1007/978-3-662-45837-2_10

J. Meyer, *Whistled Languages*,
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8.1 Preliminary Remarks About Whistled Speech Acquisition

It is important to note here that traditional training in whistled speech is accomplished by classical social conditioning in contexts similar to those of any language acquisition. Children are most likely implicitly accustomed to whistled speech signals beginning at birth—or even before—in communities where it is widespread. However, whistling always remains much less frequent than ordinary speech inside villages, and whistling is rare inside houses. According to testimonies collected in the field by various researchers in various language communities, whistled speech is generally learned soon after ordinary speech. A child who talks at 3 or 4 years old understands whistled language at 5 or 6 years old and if he lives in a village using whistled speech intensively, he begins to make himself understood at approximately the same age. However, it is only at the ages of 10–12 years old when, with his final dentition, he can produce sufficiently precise and loud modulated signals to use whistled speech at long distances.

Another important point to note is that the whistled lexicon progressively learned by a growing child has the same richness as that used in the vocal form, with the same possibility of easily integrating new words. However, whistlers generally use a preferential set of words that corresponds to the everyday activities associated with whistling. The semantic field of this specialized vocabulary is quite large, i.e., between 2,000 and 4,000 words on the Canary Island of La Gomera and in Turkey (Moles 1970; Meyer 2005), with the most common words being more easily understood, such as in specialized vocabularies of normal speech (Moles 1970; Miller et al. 1951).

8.2 A Spectacular Adaptation to Hearing and Speech Streaming

8.2.1 Human Audition and the Whistled Signal

Human audition is well adapted to a whistled speech signal and vice versa. First, the pinnae and the middle ear amplify the acoustic signals with the highest levels between 1 and 5 kHz (Batteau 1967; Borden and Harris 1980; Nedzelnitsky 1980). Next, the cochlea acts as a bank of overlapping bandpass filters that show increasing bandwidths as a function of increasing frequency (Schacter et al. 2011). Of this auditory bank, human whistled frequencies (1–4 kHz) cover the filters ranging from 120 to 500 Hz of bandwidth and activate only a few of them at a time. Indeed, according to our measures, the whistled bandwidth that emerges from the noise is approximately 400 Hz at one meter from the whistler and approximately 150 Hz at 550 m (Meyer 2005). Such a precise targeting reduces the possibilities of signal-to-signal and noise masking, which is a major advantage in comparison to a

voice signal. Moreover, human hearing acuity in the time domain is sensibly the same at all frequencies, with variations mostly as a function of the duration of the stimuli and the person's training. It is also much more precise for sinusoidal acoustic cues than for complex signals (Green 1985). Finally, human hearing is the best at selectivity and audibility in the 1–4 kHz and 75–120 dB ranges (Stevens and Davis 1938), which exactly matches whistled speech signals (at least near the emitter regarding intensity). Therefore, taken together, the psychoacoustic data show a spectacular adaptation of whistled languages to human audition.

8.2.2 Speech Streaming

8.2.2.1 Natural Speech and Stream Perception

Integration in a Speech Stream

The different perceptual attributes resulting from frequency, amplitude and duration are not perceived separately by the human brain but are integrated in a speech stream that is cut by discontinuities, permitting the organization of speech signals into syllables, words or sentences. To group the different constituents of the speech spectrum into coherent entities, humans track the fundamental frequency of the voice. They look for spectral coherence in the timbre and evaluate the rhythmical continuity of both the amplitude and the spectral envelope (e.g., Bregman and Pinker 1978; Nooteboom et al. 1978; Darwin 1981; Huggins 1975; Dorman et al. 1975; Van Noorden 1975; Wessel 1979; Chowning 2000). Studies in the domain of speech in noise or of auditory scene analysis have also highlighted the importance of sound localization, particularly in noisy environments (Bronkhorst 2000; Bregman 1990). We saw, for example in Chap. 7, that for both tonal and non-tonal languages, whistled speech is already composed of a clear and coherent stream that incorporates the results of some of these procedures of fusion and segmentation.

Amplitude and Frequency Modulations

An important aspect of a whistled speech signal is that it is highly characterized by amplitude and frequency modulations encoding whistled vowels, consonants and tonal melody. Several studies have also shown the importance of modulations for speech recognition in standard speech. For example, Marin and McAdams (1991) have studied the prominence of modulated vowels compared to non-modulated vowels. They have concluded that the coherent, sub-audio frequency modulation of a harmonic sound source contributes to its segregation from other concurrent sounds if the modulation width is large enough. Another interesting example is the study of Darwin (1981), who has analyzed the effect of coherent modulations over the entire spectrum of an initial consonant in a Consonant-Vowel context (CV),

underlining that both frequency and amplitude modulations provide a better perceptual value to a CV utterance compared with an isolated phoneme. At the large scale of a full sentence, the most important frequency modulations of the speech stream were found to be those combined with rapid amplitude modulations typically associated with the articulatory movements of opening/closing, constrictions, and coupling/decoupling of resonant vocal cavities (occlusive, affricates, nasals and the laterals /l/ or /r/). Indeed, the combinations of frequency and amplitude modulations preserve the relative location of events by perceptually signaling line edges and other narrow events (Oppenheim 1979). Interestingly, Zeng et al. (2005) have even shown that such information is critically needed in challenging tasks, such as speech recognition with a competing voice or in noise (Zeng et al. 2005). These results provide additional elements of explanation for the particular efficiency of whistled speech in noise and in full sentence contexts.

8.2.2.2 Comparison with Sine Wave Speech Signals (SWS)

Studies on SWS signals are also of interest to better approximate the reality of whistled speech perception in non-tonal languages because both types of signals share the particularity of being based on whistle-like signals and are completely unintelligible to people unaware that they encode speech. SWS is a form of artificially degraded speech first developed at Haskins Laboratory. Sine wave synthesis is a technique for synthesizing speech by replacing the formants with pure tone whistles. Together, the three or four sinusoids derived from the first three or four formants of the spoken voice replicate the estimated frequency and amplitude pattern of the resonance peaks of a natural utterance (Remez et al. 1981). Consequently, consonant and vowel formant modulations are encoded in such signals (signaling, for example, onsets and offsets of non-continuous consonants). Strikingly, several experiments on the perception of sine wave speech have shown that it is an intelligible synthetic acoustic signal. However, Remez and colleagues have demonstrated a dramatic change in how SWS sentences are perceived, depending on listeners' specific prior knowledge. Most naive listeners hear such sentences as a set of simultaneous whistles. However, for listeners who have previously heard the spoken equivalent, listening to the SWS sound produces a very different perception of a fully intelligible spoken sentence that sounds like robot speech. After a short phase of training, this ability is generalized to all SWS signals. Such a dramatic change in perception has been interpreted by Davis and Johnsrude (2007) as an example of "perceptual insight" or pop-out. Moreover, they have argued that this form of pop-out is an example of a top-down perceptual process produced by higher-level knowledge and expectations concerning sounds that can potentially be heard as speech. Crucially, and just as for whistled speech, the perception of the linguistic properties of SWS depends on sensitivity to acoustic modulations stripped of many acoustic constituents of a natural voiced signal. Consequently, proof of the intelligibility of such signals invites researchers to consider the importance of the dynamic patterns of trajectories in normal speech cognitive treatment.

The fact that whistled speech requires more training than SWS is also interesting because it reflects that the modulations are even more different from normal speech than the sine waves of formants (see more results on this point in this chapter).

8.3 Behavioral Experiments on Whistled Languages

Several experiments have shed light on how whistled speech is recognized by whistlers and non-whistlers. Most of them have focused on the adaptation of the complex spectral and formant distribution of spoken voice into whistles in non-tonal languages because it is one of the most peculiar and instructive aspects of whistled speech, showing that the multidimensional frequency space of spoken vowel and consonant qualities can be associated by the human brain to a mono-dimensional whistled space. The protocols that have been chosen by the experimenters are very diverse. They reflect their scientific background and the conditions of use of whistled speech in each place. They are ordered here as a function of the increasing complexity of the stimuli presented to the participants. We first address experiments testing recognition of isolated phonemes. Next, we examine experiments dealing with nonsense CV or VCV utterances. Finally, we discuss the results of intelligibility tasks for words and sentences.

8.3.1 Perception of Whistled Vowels by Non-whistlers (And by a Reference Whistler)

Some whistlers encountered on La Gomera Island asserted that the task of recognizing whistled utterances relies on the perceptual capacities already developed by speakers for spoken vowels and that this explains why anyone can speak in whistles and recognize speech in whistles. We quickly observed that we could intuitively recognize some vowels and words that were whistled by very good whistlers. To investigate, I decided to conduct two experiments in which categorization of whistled vowels was observed for subjects who knew nothing about whistled languages (French students).

8.3.1.1 Design

Four vowels from the Spanish whistled language of La Gomera (Silbo)—also existing in French with similar or close pronunciations—were tested: /i/, /e/, /a/, and /o/. Sounds played in the first experiment included the vowel nucleus without the consonant modulations. The stimuli of the second experiment kept 2–3 s of the whistled sentence preceding the vowel (to test the effect of the acoustical context

and to eliminate bias that might appear because of presenting nearly pure tones – here isolated vowels—one after another). In each experiment, participants listened to a whistled vowel and immediately afterward selected, in a four-alternative forced choice (4-AFC), the vowel type estimated to be closest to the one heard. Twenty non-whistlers and one traditional whistler listened in the first experiment. Twenty other non-whistlers listened in the second experiment. There were six musicians in each group of naïve listeners.

8.3.1.2 Results

The high level of correct answers (87.5 %) obtained by a native whistler of La Gomera on isolated vowels (the most difficult task) confirmed that the task was relatively easy for whistlers, and he was able to accurately identify the four whistled vowels [X2(9) = 136.97, $p < 0.0001$] (Meyer 2008). This finding was important because it led us to reject previous researchers' assertion, made without any proof, that whistlers of La Gomera were whistling only two vowel types, which they called "acute" and "grave" (Trujillo 1978 originated this erroneous theory). Rejecting this pure invention was important because Trujillo's work was taken as a reference for didactic applications in the revitalization project of Silbo launched in primary schools on La Gomera Island [see one official teaching manual intended to be used by teachers of Silbo (Trujillo et al. 2005)]. Moreover, Trujillo (1978) was also the only reference cited by the only neuroscience study of a whistled language (Carreiras et al. 2005).

Moreover, for the correct identification of isolated vowels, even the 20 French non-whistlers achieved a general rate of 55 %, with variations as a function of the vowels (78.44 % for /i/, 46.88 for /e/, 44.06 % for /a/, and 50.63 % for /o/). Considering the protocol and the task, these results were largely above chance and showed that naïve French listeners succeeded in categorizing the whistled emulations of /i, e, a, o/ without any preliminary cues on the phenomenon of whistled languages. This situation even applied in the training phase, which was simply designed to accustom the participants to the task. The results of the 20 other French naïve listeners participating in the second experiment (with vowels in context) showed the same general tendencies but with slightly better performance on the identification task: 60.2 % [X2(9) = 1201.63, $p < 0.0001$] (Meyer 2008). Moreover, in both experiments, most of the confusions were logical because a whistled vowel was generally confused with its neighboring-frequency whistled vowels (see details in Meyer 2008). Another interesting finding of these experiments is that musicians performed better than non-musicians on isolated vowels but not in vowels in context. This observation can be explained by the fact that musicians are trained to associate an isolated pitch with a culturally marked sound reference.

The fact that naïve listeners could categorize whistled vowels as trained whistlers would, even during the training phase, shows that they were already familiar with a perceptual representation of the vocalic inventory in the frequency scale. This observation suggests that a representation with /i/ identified as an acute vowel,

/o/ as a low vowel and /e/ and /a/ in between—with /e/ being slightly higher in pitch than /a/—plays an important role in the process of identifying the spoken French vowels /i, e, a, o/. Therefore, these experiments also confirmed that whistlers rely on a perceptual reality at play in spoken speech to transpose the vowels to whistled frequencies.

8.3.2 Nonsense Utterance Perception by Whistlers

The results of four different perceptual tests with nonsense utterances have been published. The first was conducted by Busnel with the last Béarnese whistlers of Aas (Busnel et al. 1962). The second and third were performed by Moles in Turkey during the expedition organized by Busnel in 1967 to the region of Kusköy (Moles 1970). The last was led by Rialland on La Gomera Island with traditional whistlers of local Spanish (Rialland 2005). In these four experiments, nonsense tokens were used to control for possible interference from lexical frequency effects.

Before analyzing the results of these experiments, it is necessary to note that the inhabitants of these areas are completely unfamiliar with the exercise of recognizing utterances without signification. In Turkey and Aas, the tested whistlers were illiterate. For the tested whistlers of La Gomera, it is possible that they had some reading experience because one taught Silbo in school. Moreover, in general, for traditional speakers in rural areas, listening to such utterances is an abstraction that makes no sense.

8.3.2.1 Tests with CV Logatoms of Vestigial Béarnese

Béarnese-Proficient Whistlers as Listeners

Busnel et al. tested a limited number of CV utterances with two Béarnese whistlers of Aas. The complete list of stimuli was made from a combination of vowels and consonants of the Béarnese language: /p, b, k, g, d, t, m, n, je, r/ and /a, i, o, e, u, õ/. For example, for the consonant /p/, the stimuli were /pa, pi, po, pe, pu, põ/. One whistler stood inside a soundproof box, where he was asked to whistle the different stimuli. Another whistler listened to these CV utterances (called also logatoms) broadcast by a loudspeaker in another soundproof box at the laboratory of Physiologie Acoustique in Jouy en Josas (France). Some video extracts of this experiment are available (Busnel 1964). The detailed results have been published by Busnel et al. (1962) in the form of a matrix, where coefficients of intelligibility have been calculated for each CV utterance. The exact formula used by those authors to obtain these values is not indicated. However, a later publication made by a member of Busnel's team (Moles 1970) indicates that it consisted of applying a different weighting to consonants and vowels, which was consistent with the norm at that time in the domain of telephony (consonants: 2; vowels: 0.5). Therefore, the general

percentage of correct recognition—37 % for one whistler (Mr. J) and 50 % for the other (Mr. C)—derived from these values is influenced by such weighting and cannot be directly compared with tests that do not apply this weighting.

Turkish-Proficient Whistlers as Listeners

Another experiment made with this material consisted of testing the recognition of the same Béarnese CV utterances by three whistlers of Kusköy. This experiment is briefly explained in Moles (1970). Only 20 CV utterances from the original recorded corpus were used. The same weighting of vowels and consonants was applied to percentages of recognition. It seems that the experimenter was inspired by the status of whistled Turkish as a real telecommunication system to choose to evaluate the efficiency of the utterance recognition in the same way as telecommunication engineers of that time. The results for the three good whistlers were, respectively, 22 % (Al), 27 % (Se) and 34 % (Os) correct answers. These percentages are slightly lower than for native Béarnese whistlers. Such a difference in the participants' performance is logical given that the inventory of consonants and vowels differs in each language. However, the results show a very interesting point: the whistlers of non-tonal languages can phonetically recognize utterances articulated in other non-tonal languages.

8.3.2.2 Turkish Logatom Recognition

Design

Moles (1970) also studies the perception of whistled Turkish CV logatoms[1] by 5 males identified as very good Turkish whistlers by both the community and the researchers. In total, approximately 120 CV utterances were heard by each whistler. VCV and VC utterances were also tested. However, Moles provides only very general results.

General Results for CV and VCV Utterances

The recognition scores on CV stimuli performance are summarized in Table 8.1. Again, it seems that the percentages provided by Moles were computed after applying a typical telecom weighing of the data because these results were presented in the same article that provides the results on the recognition of Béarnese syllables by Turkish whistlers. Moles's text is not very clear on this aspect. The rates of identification of the CV utterances are lower than 33 % but higher than 12.5 %,

[1] Logatoms are non-words that follow the rules established for telephonic needs.

Table 8.1 Recognition performance of CV utterances (adapted from Moles 1970: 85)

Whislers (% mean)	Ad (22 %)	Be	Al (25 %)	Os (20 %)	Sa (22 %)
Ad (16.6 %)	–	16.25	22	12.5	
Be	22.5	–			
Al (20 %)	19		–	17.50	24
Os (22 %)	23.75		21.25	–	21
Sa (31 %)			32.5	30	–

depending on the pair of whistlers. Interestingly, the recognition rates show differences in the aptitudes of emitters (mean values in rows) and receivers (mean values in columns). The percentages given under the name of each emitter (1st column) and each receiver (1st row) give an idea of the disparity. Such inter-individual differences may be partially due to the difficulty experienced by some whistlers in performing to such a degree of abstraction, given that that all had been previously identified as good whistlers in both production and perception. According to Moles, the best emitter-receiver couple was Sa-Al: the best receiver was Sa and the best emitter was Al. Moreover, differences in performance for different logatoms have been noted by Moles, but no quantification of these differences have been published. Conversely, when discussing his results, Moles has mentioned that the performances on CV stimuli were far lower than on the VCV utterances that he also tested, whereas similar performances were obtained with VC stimuli. According to him, VCV improved results in the range of 21–32 %, but unfortunately, he has not provided further details. Arguably, consonants lose certain temporal and frequency aspects in CV and VC contexts that are present in VCV contexts.

Vowel Recognition

This recognition test on CV logatoms was particularly adapted to the study of vowel perception. Therefore, confusion matrices for vowels and diphthongs were derived from these results. Moles (1970) writes that several matrices are analyzed, each corresponding to a pair of whistlers (emitter-receiver) but some of them were published. From his results, we observe that all of the intervocalic confusions are coherent with the statistical distribution of vowel frequencies presented in Chap. 7. Indeed, vowels whistled at close frequencies are much more confused than are vowels at distant frequencies. Moles notes that he is particularly struck by the relative stability of [i] and the selective confusion of [e] with [œ, [aj] with [oj], [a] with [o] and [ʊ] with [œ]. Only one of the most salient confusions seems incoherent with the frequency statistical groupings we found in Chap. 7. It concerns the fact that [ʏ] is quite often taken for [œ], whereas [œ] is never taken for [ʏ]. However, it is coherent with the frequency distribution of Turkish vowels shown in Chap. 7 (Fig. 7.1c) where [œ] and [ʏ] are the whistled vowels that overlap the most with vowels of other groups. In a more realistic situation involving the recognition of whistled words instead of logatoms, such confusions would be neutralized. Therefore, the overall perceptual results

on whistled Turkish vowels confirm that the phonetic reduction applied by the whistled transformation phonetically reduces the vocalic system into four intervals of simple vocalic whistled frequencies that can be related to proximities in the articulation of spoken Turkish vowels. It also confirms the importance of Turkish vowel harmony rules to unravel completely the recognition of whistled vowels in Turkish.

8.3.2.3 VCV Utterance Perception in Silbo

Design of the Test

Rialland (2005) has conducted a perceptual test with VCV utterances to test consonant identification. One pair of whistlers (emitter-receiver) identified as L-A participated in the experiment. The consonants played in the test were /p, t, k, ch, b, d, g, f, s, m, n, ñ, l, r, rr, j/. From the data provided in the appendix of Rialland's article, we calculated that the experiment principally tested /t/ (n = 16), /g/ (n = 9) and /p/ (n = 9), whereas /b, n, m/ occurred four or five times and the other consonants occurred less than three times. For vowels, the distribution was as follows: /a/ (n = 89), /o/ (n = 22), /i/ (n = 19), /u/ (n = 4) and /e/ (n = 2). The VCV context was chosen because of its high frequency in Silbo and because it provides transitional cues on both sides of the consonant, a favorable circumstance for recognition. The participants were asked to stand fifteen m apart on a hillside. During the testing, each participant was recorded independently. The test tokens, such as /*ota*/ and /*iti*/, were whistled by one of them, and the other was asked to repeat the whistled utterance and to say aloud what Spanish VCV sequence he heard. At this point, the whistler indicated whether the utterance had been correctly identified or not. The test itself was preceded by a short training session. Part of the test was filmed and can be viewed in a video documentary that originated the study (Jampolsky 1999).

Results

The overall percentage of correct identification of VCV was 57 % (39 correct answers out of 68 answers or non-responses). Rialland also finds that identification varied considerably depending upon the phoneme. She states that /t/ and /p/ were well recognized, while /r/, /rr/ and /l/ were not correctly identified even once (Rialland 2005). However, we can note that /l, r, rr/ occurred, respectively, only 1, 2 and 3 times, which is not enough to ground a solid analysis. Additionally, we found that the four most-represented consonants were correctly identified at a rate of 58.8 %. We found 77.7 % correct answers for /p/ (once taken for a /t/ and once for a /k/). We also found large differences between individual consonants, as 68.75 % of /t/ were correctly identified, whereas /g/ was often taken for /b/ and was recognized at a rate of 22.2 %. Rialland notes that velar sounds generally tended to be confused with labials, most likely because they were realized with falling frequency modulations similarly to labials. There was one exception, namely, the syllable *ka*, which was realized with no

transitional movements (similarly to spoken *ka*) and was recognized in the 3 cases. Moreover, she finds that recognition performance for continuous and non-continuous properties of phonemes was high (87 %). As shown in Chap. 6, “continuous” consonants show no full interruption but do show an intensity dip, and “interrupted” consonants show only a clear interruption.

Although the test was not made for vowel identification, we found that the most represented vowels /a, o, i/ were identified at rates of 94.4, 59 and 78.9 %, respectively. Unfortunately, the test was insufficient to conclude anything on /e/ because it appeared only twice. Rialland notes that /*o*/ and /*a*/ were not merged in production and that they were sometimes correctly distinguished in perception, with *a* receiving a higher identification score than *o*.

The results of this test and the organization of the stimuli were important to mention here because they served as a basis for the analysis of the phonological features of Silbo provided by Rialland earlier in her article.

8.3.3 Intelligibility of Whistled Words

8.3.3.1 Design

Whistled word recognition was studied by Busnel (1970) in Turkey with 5 different whistlers who each listened to between 45 and 50 words in whistled and spoken form. The words were broadcast by loudspeaker. The whistler listening to the sounds stood ten m from the loudspeaker. The corpus intentionally included words that could be easily mistaken for one another because they were Turkish minimal pairs that differed only by one consonant, such as /bana/ and /sana/, /ormana/ and /osmana/, /kapici/ and /yapici/, /bakalim/ and /yakalim/, /parali/ and /yarali/, /yüzonbir/ and /yüzonbin/. All of the words were selected among a list of 180 words constituted during the expedition as representing the most common whistled words of Turkish (see Moles 1970).

8.3.3.2 Results

Table 8.2 synthesizes the results that were found in the various different tables and categories in the original study (Busnel 1970). The general level of correct answers for isolated whistled words was relatively high (69 %), but we immediately observe that this value contrasts strongly with the 96.6 % correct answers for standard speech. This result confirms that at short distances and without the lexical context of the sentence, the spoken voice is much more efficient than whistling. The few errors made on spoken words were perhaps due to minimal pairs, giving an idea of the difficulty of the task. There was much less inter-individual variability than for CV utterances.

Table 8.2 Word recognition performance of 5 different whistlers for the same word list (adapted from two different tables in Busnel (1970: 46, 49)

Receiver	Spoken speech (strong speech)	Whistled speech
	Correct answers (%)	Correct answers (%)
Al	88.8	68.9
Os	95.7	62.2
Sa	95.6	76
Ad	100	66.7
Me	100	71.1
Total	96.6	69

8.3.4 Intelligibility of Whistled Sentences

8.3.4.1 Tests in Spontaneous or Semi-spontaneous Situations

When whistlers speak at a distance, they choose their sentences depending on the context and on the proficiency of their interlocutor. Moreover, if a sentence is not well understood, the receiver will ask for a repetition, and the emitter will generally repeat the exact same sentence at a slower pace with a focus on the clarity of the articulation. If the receiver still does not understand, the emitter will often simplify his sentence or use another one with the same meaning to ensure that the information is understood. Therefore, it is not rare to find that 100 % of the information the emitter wanted to transmit is ultimately understood by the receiver.

Several observations of spontaneous or semi-spontaneous observations leaving the whistlers free to choose their own sentences have been performed by various researchers in the field with different methodologies. For example, Cowan (1948) is the first to try to quantify the amount of information that could be sent by Mazatec whistlers through whistling after having observed and transcribed full sentences exchanged by whistlers (the whole translated conversation was as follows: “Mr. A: What did you buy? Mr. B: It is a load of corn. Mr. A: And where do you bring it? Mr.B: I bring it to Tenango. Mr. A: You are going to sell it? Mr. B: I will sell it. Mr. A: How much? Sell it to me here. Mr. B: It will be two pesos and fifty centavos for the volume? Mr. A: Don’t you want two pesos and twenty-five centavos? That is what I can give you. Mr. B: Where I go to sell, they would give me three pesos. Mr. A: Yes, but it is far. What do you decide? Mr. B: I will leave my load here. Mr. A: Great, you were asking a lot” (Cowan 1976: 1396, free translation from Spanish).

Meyer (2005) relates another type of observation with Greek whistlers, in which he proposed a topic to an accomplice whistler and let the conversation flow while he was recording the exchange. He found 95 % intelligibility for sentences without any repetition necessary. The sentences were rather short but were composed of up to 9 words, and they exactly followed the syntactic structure of ordinary Greek sentences. The 5 % unintelligibility in the understanding of one of the interlocutors during contact in the distance was most likely due to time lapses necessary to focus

attention on the emitter. However, the same conversation was perfectly understood (100 %) by the daughter of one of the whistlers, who was the one performing the simultaneous translation for the researcher (Here is an extract of the experiment showing the kind of sentences that were said: Mrs K: /Kaˈlos ˈirθae ti θelete/ (*Welcome, what do you want?*). Mr. P: /Parakaˈlo ˈθelo na ˈfao/ (*Please, I would like to eat*). Mrs. K: /Ine ˈdaksi/ (*All right*). Mr. P: /Boˈro na ˈexo omeˈleta/ (*I would like scrambled eggs*). Mrs. K: /ˈMi stenaxoˈɟeste, efxariˈsto/ (*Please don't worry, thank you*). /Θa ˈpçite kafe ce meˈta piɟede ˈopu ˈθelete/ (You'll have a coffee and then go where you want). /Kaˈlo taˈksiδi ˈlaura ce tzuˈʎano/ (I wish a good trip to Laura and Juliano).[2]

The latest published experiment of this type was another semi-spontaneous dialogue presented in a video extract included in a recent article by Moore and Meyer (2014) on Gavião tone language (the full transcription and translation of the dialog is provided in the video included in this publication).

Another researcher designed an innovative test that is explained and partly shown in a video documentary called "Whistles in the mist" (Sicoli 2012; Yetman 2013). The general idea was to test how well whistled Chinantec speech could be understood and whether it could be used outside of its regular context. He created a map navigation task. One person had a map and was free to choose a course on that map to move from a starting point to an ending point. The other whistler had the same map of an imaginary town. Without the other person seeing what he was doing, the first whistler used whistles to help his interlocutor navigate through his map. According to Sicoli, the test was successful because the two started at one place and reached the destination, moving through the town streets, simply by giving instructions through whistling. A complete analysis of the exchanges continues to await publication. The analysis will be interesting because it will be one of the rare perceptual tests of tonal whistled speech. The Chinantec language is very tonal. It has 7 different tones and two stress levels, resulting in a tonal structure that carries a heavy load of information for sentence intelligibility (Foris 2000).

In the next section, we will present tests addressing sentences given to the whistlers to evaluate intelligibility. This approach is the most common way to measure sentence intelligibility in the psycholinguistics of spoken speech.

8.3.4.2 Sentence Intelligibility for Three Different Categories of Given Sentences

Design

A sentence intelligibility test was organized in Turkey by Moles (1970). The test included listening to 30 different sentences composed of three to seven words.

[2] We would like to thank Dimos Kostis who checked and corrected our transcriptions. Stressed syllables are here marked by a "ˈ" symbol preceding the syllable.

The experimenters grouped the sentences into three categories of difficulty. The exact factors explaining the classification of sentences by level of difficulty were not clearly explained by Moles, except for the third group (called group III), which was said to be composed of nonsense surrealistic sentences. However, the entire list of sentences available in Moles (1970) enabled us to find additional distinguishing criteria. First, the sentences of the first group (group I)—judged as easy by the experimenter—were generally composed of three to four words and addressed activities performed at school (“Do you have a pencil?”, “Close the entrance door”, “Will we go at school tomorrow?”), in the village or sometimes in the surroundings (“I can’t go to Görele tomorrow”). Only some of them corresponded to actions matching the context of shepherding, which is the primary activity of whistlers in the region (see for example the sentences “Let’s go cut trees”, “Don’t leave the herds on the opposite slope” of group I in Moles 1970: 90–95). The sentences in the intermediate category were generally longer (up to 6 words) and addressed more abstract concepts than those of group I (see sentences “Did you learn that your brother will leave for the military service?”, “The birds are in the clouds above the opposite hill” in Moles 1970: 90–95). The difficult sentences of the third group were not longer, except for one, but they consisted of nonsense meanings such as: “I will eat stones”, “Fix your eyes on the horizon to see tomorrow” or “The police attacked the police office”. All of the sentences were whistled by the same good whistler (Os). Three participants—good whistlers, according to the community (Me, Sa, Al)—listened to them at the same time. The listeners were separated from the emitter and the other receivers by a distance of approximately 20 m. Each one told an experimenter what he had understood.

Results

The author of this study didn’t provide any precise analysis based on the on the lists of answers published in Moles (1970). His only commentary is that the first group of sentences was at the level of “mastering intelligibility”, the second was at the limit (approximately 50 %) and the more abstract sentences were not well recognized. However, because the original data are available, we computed the recognition rates of words, but first, we excluded one sentence from the first group and one from the second because they included the word “truck”, which was an essential element of their meaning [sentences 5 and 20 in Moles (1970)]. This exclusion was made because Moles himself mentioned that this word had been very recently introduced in the region and had no reality for many older villagers of Kusköy in their 70 s (see Chap. 3 about the recent arrival of motorized vehicles in this region when the study was made in 1967). Moreover, several different words could be used for “truck”.

The general word recognition performance calculated from the sentences of group I (easy) was 70 %, with a great variability between whistlers: Sa recognized 86.7 % of the words, whereas Al and Me recognized 70 and 56.7 %, respectively. Such relatively “low” results compared to the objective of complete and perfect communication can be explained by the fact that not all of these sentences

concerned the most common context of use of whistled speech. For sentences of group II (medium), the general success in word identification was 55 %, this time with Al being the best performer (79 %), followed by Sa (47 %) and finally, Me (38.6 %), who was definitely the worst receiver of these sentences. In the abstract nonsense sentences (group III), the recognition rates were 33.3 % for Me, 18.2 % for Sa and 15.2 % for Al. Curiously, the worst receiver of the two first sentence groups was the best at the most difficult task. Perhaps he is an innate surrealist! A better explanation is that the other whistlers tended to attempt to build coherent sentences, whereas Me was more focused on individual words.

8.3.5 Conclusions on the Intelligibility and Behavioral Tests

In real conditions of use, good whistlers manage to transmit 100 % of the sometimes-complex information they want to transmit, with sentences that they choose and sometimes repeat. In psycholinguistic tests in which sentences were chosen by experimenters, the best whistlers managed to understand between 70 and 86 % of the words. When the sentences were even more complex, this rate dropped. Traditional whistlers had a very difficult time understanding nonsense sentences that were written by one of the experimenters. Conversely, isolated word identification reached approximately 70 % accuracy in Turkey, with relatively little inter-individual variability. Such results are very valuable because they were obtained at a time when whistled speech was still widespread and extensively used in the region around Turkey's Kusköy village, with a language showing a large inventory of vowels and consonants. In similar conditions of whistlers' listening and proficiency, whistled words were much better identified than whistled VCV in both Turkey and La Gomera (20–30 % increase in recognition rates). Moreover, the results that we examined for CV or VC utterance recognition are much lower than for VCV utterances (by approximately 20–40 %). The difference in performance between CV and VCV tokens shows the importance of amplitude and frequency modulations for consonant identification in whistled speech. Such modulations sometimes carry important information in the time domain, as seen in Chap. 6. The intercultural test addressing the recognition of whistled CV patterns in Béarnese by Turkish whistlers confirmed that modulations are perceived similarly in consonants of different non-tonal languages. The results of approximately 20–30 % success were far above chance, which was situated at 5 %, and were similar to the recognition of whistled Turkish CV patterns by the same Turkish whistlers.

Moreover, analyses of vowel recognition all show differences of treatment between vowels. /i/ is often the best recognized. They also confirm that whistlers may confound some of the vowels because the frequency reduction from spoken to whistled registers restrains the vocalic range to three or four dominant intervals of whistling. The categorization test of whistled Spanish by non-whistlers shows that the frequency distribution of whistled vowels is perceptually relevant to non-whistlers. Indeed, French subjects knowing nothing about whistled languages

categorized Spanish whistled vowels /i, e, a, o/ in the same way as Spanish whistlers, even without any training. This finding suggests that the listeners already have in their cognitive representation a frequency scale to identify spoken vowels. It also supports the assertion of whistlers who affirm that they rely on a perceptual reality of spoken speech to transpose vowels into whistled frequencies.

From the perspective of perception, the prominence of close formants is the most coherent explanation of the recognition performance of both whistlers and non-whistlers in non-tonal languages, even if, from the perspective of production, we saw in Chap. 4 that formants 2 and 3 are the most likely to be whistled for acute sounds. For example, it has been shown that in the spoken form of speech, a greater formant convergence explains the better performance in vowel identification and the better stability of vowels in short-term memory. The perceptual data generally confirm the clear distinction between /i/ and other vowels. They also confirm that the grouping of posterior and central vowels found in the analysis of production in two different categories is also explained by these considerations of formant convergence. This result is perceptually coherent with the fact that human hearing is highly sensitive to the convergence of, for example, F3 and F4 for /i/, F2 and F3 for /e/, and F2 and F1 for both /a/ and /o/ (Schwartz and Escudier 1989).

8.4 Neural Processing of a Whistled Language

Thus far, only one neuroscience study has addressed the neural processing of a whistled language (Carreiras et al. 2005). Recorded samples of spoken and whistled Spanish sentences and isolated words were presented to proficient whistlers (Silbadores) and control participants unfamiliar with Silbo Gomero. The participants were subjected to listening tasks. First, they listened passively to Silbo and to Spanish sentences against a baseline condition of digitally reversed Silbo. In the second task, participants were asked to monitor cycles of Silbo "words" and Spanish words intermixed with silent periods.

The results show that brain areas normally associated with the spoken-language function are also activated in proficient whistlers (but not in naïve Spanish listeners) presented with audio recordings of whistled Spanish words. More precisely, the authors of this pioneering study first found that the temporal regions of the left hemisphere, which are usually engaged during the processing of spoken language, were activated by Silbo whistled Spanish of La Gomera in the brains of the experienced whistlers but not in the controls.

Both passive listening and active-monitoring tasks produce a common activation in the left superior posterior temporal gyrus of the whistlers. These results are important because they provide an additional proof that whistled words are considered by whistlers to be speech utterances in which they can look for phonetic contrastive features even if they are completely unintelligible to the controls. In this sense, the experiment was very similar to a speech versus non-speech stimuli study, with different populations for each condition but strictly identical stimuli.

Testing this type of contrast, i.e. speech versus non speech, has attracted much attention during the past few years but represented a difficult challenge in early experiments because they used speech and non-speech stimuli that differed in their acoustic properties so that any reported difference in brain activations could be attributed to differences in the acoustic features of the stimuli (Binder et al. 2000; Burton et al. 2000; Celsis et al. 1999; Jacquemot et al. 2003; Vouloumanos et al. 2001). By using whistled speech signals, Carreiras and his colleagues managed to use the same stimuli for both conditions, but the limitation was that the same subjects were not tested for both conditions because proficiency in Silbo perception requires effort and a relatively long training period (as explained in Sect. 8.1). However, after the study of Carreiras et al., some other teams of researchers have succeeded in employing Sine-Wave-Speech signals (SWS) instead of human made whistles in order to present the same type of stimuli on the same subjects given that such stimuli have the advantage of being perceived as mere science fiction sounds before training and a fully intelligible robot-like voice after a short training phase with some sentences (see Sect. 8.2.2.2). With SWS, enhanced activity in cortical regions was found in the left hemisphere after training, namely, the left posterior superior temporal sulcus and the left posterior superior temporal gyrus (Dehaene-Lambertz et al. 2005; Möttönen et al. 2006). The left posterior superior temporal gyrus, which was also activated by whistled Spanish, is now known to participate in high-order auditory processing and to encode an acoustic-phonetic representation of ordinary speech, which could have important implications for the categorical representation of phonemic systems (Mesgarani et al. 2014).

Another point about the results obtained by Carreiras and colleagues is that it is possible that the documented left activations in the brain does not reflect phonological processing because the stimuli consisted of full words (with morphology and semantics that also promote left activations) (Minagawa et al. 2011). Clearer evidence to this effect would come from studies using meaningless but phonologically and phonetically well-formed whistles, such as the VCV or CV utterances of Sect. 8.3.2 in this chapter.

Additionally, in the study of Carreiras and colleagues, activation of the right-hemisphere superior-midtemporal region has been found across both the Silbo and Spanish speech conditions. Here we may note that such regions generally respond to non-linguistic pitch changes, tones and complex sounds (e.g. Warren and Griffiths 2003). Interestingly, brain imaging studies on pitch in tonal languages have already shown that simple pitch patterns are lateralized to the left hemisphere speech zones only when they are phonologically significant (Sittiprapaporn et al. 2003; Xu et al. 2006). The study on Silbo confirms this result and extends it to signals that emulate segmental phonologic distinctions with pitch rather than suprasegmentals of tone languages. This confirms that the brain areas associated with speech in the left hemisphere mediate the processing of linguistic information for any type of contrastive phonetic features regardless of acoustic cues or type of phonological unit, whether segmental or suprasegmental (Zatorre and Grandour 2008).

Moreover, Carreiras et al. note that less ventral-anterior temporal activation was observed during Silbo processing than during speech processing tasks that the listeners performed. An anterior-ventral system might be used for analyzing and mapping complex sounds onto lexical representations. Therefore, here, it is possible that the “categoricalness” or phonological relevance of auditory stimuli triggers a link to anteroventral regions that contain stored representations (Zatorre and Grandour 2008). The lesser activation in Silbo shows the plasticity of the brain to different signals. A possibility is that Silbo imprints a phonetic simplification that hinders some phonological contrasts of Spanish (as shown in Chap. 7). However, the phonemic reduction is not as drastic as what Carreiras et al. refer to when citing Trujillo (1978) whose theory hypothesizing that the full phonemic inventory of Spanish is reduced to only two phonologically contrasting vowels and four consonants has been proven erroneous (Meyer 2008).

Finally, Carreiras et al. have found that for both speech and Silbo processing, the posterior temporal cortex was activated in a region that is involved in articulatory-gestural representations. The presence of premotor activation (tongue and lip representation) that is involved during Silbo communication is consistent with this interpretation (Carreiras et al. 2005).

8.5 Conclusions and Perspectives

This chapter provided an overview of past and present research on whistled speech perception. We saw that the behavioral and neuroimaging experiments based on this peculiar speech register have mostly focused on analyzing formant-based whistling because it has the intriguing particularity to cognitively map the complex vocal tract resonances characterizing vowels and consonants to a simple sine wave. So far, pitch-based whistling has attracted less attention because it relies on a more direct association with the pitch of the voice. The results of these experiments show that recognizing whistled speech requires training but is rooted in the way vocal standard spoken speech is produced and recognized. Given the phonetic reductions imposed by whistling to vowels and consonants whistled speech recognition is generally less efficient than for spoken voiced speech, at least in the conditions of the tests that were made so far (that is, at very close range and low noise levels). For example, Table 8.2 provides a good basis of comparison because it shows that voiced words are recognized at a mean rate of 96.6 % whereas whistled words are recognized at a mean rate of 69 %, with little variability between well trained traditional whistlers. However, it is important to remember that whistled forms of languages target special circumstances of speech communication associated to distance. When the range of spoken communication increases, standard speech rapidly losses efficiency and whistling is more efficient than standard speech. For example, in Meyer et al. (2013) we studied the intelligibility loss of spoken words with increasing listener-to-speaker distance in a typical low-level natural background noise (with a noise characteristic of the most regular and frequent acoustic

constraints encountered outdoors in ecologically valid contexts, see the definition of "natural quiet" in Chap. 6). The noise was combined with the simple spherical amplitude attenuation due to distance, basically changing the signal-to-noise ratio (SNR). The results show that word recognition performances are lower than 70 % at already 17 m from the emitter. At greater range, whistled speech would be more efficient than standard speech. We also found that the best recognized consonants where sibilants (that is, with whistle-like sounds) that are still recognized at rates above 90 % at 33 m. Whistled speech inspired the design of this last study. It is eager to inspire other perceptual studies of this type or of the type presented through this chapter, serving as a model to test targeted functionalities of the human brain and key properties of human language. It is a promising branch of research (Patel 2008) that remains little studied.

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Chapter 9
Evolutionary Perspectives

As we have seen in the previous chapters, whistled speech is a phonetic adaptation of humans' most elaborate and specific communication systems—languages—mostly for distance and without-sight talk in natural surroundings, particularly for traditional survival activities involving hunting, pastoralism and agriculture (food supply activities) but also for singing and poetry and to guarantee the secrecy of information in some specific circumstances. The simple voiceless melody of whistling emulates selected characteristics of the voice and fulfills the essential communicative functions of language. Therefore, this peculiar practice has the advantage to provide an alternative insight into language communication. Concepts such as "adaptation", "distance communication", "survival activities", "group coordination", "mimesis" and "prosodic language" are often invoked in current debates on the evolution of language. Therefore, in this last chapter, we will further explore some characteristics that make whistled forms of languages good candidates for the study of the evolution of speech and, more generally, the language faculty in humans. First, we will observe how the most recurrent traditional activities and techniques of whistling are generally associated with specific socio-environmental contexts of human settlements (or ecological niches). Next, to understand better the idiosyncrasies of human whistles, we will explore some convergences/divergences with whistled communication among animals (birds, dolphins and primates). For example, we will examine cues suggesting an acoustic adaptation of whistled speech signals to the biotopes and compare it with adaptive acoustic behaviors found in animal whistled communications. We will also focus attention on recently discovered acoustic behaviors in orangutans which reveal that these apes are able to control voluntarily some of their oral articulators (they manage to whistle or to adapt their alarm call by employing a vibrating leaf). Finally, in the last section of this chapter, different important questions raised by the origin and the evolution of whistled forms of languages are explored, including the role of environmental constraints in the emergence of whistled speech, the hypothesis of a whistled system preceding voiced speech, monogenesis and polygenesis scenarios of whistled speech, the intricate relationship between music and language in whistling.

J. Meyer, *Whistled Languages*,
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9.1 The Ecological Niche of Human Whistlers

In the previous chapters, ethnographic and bioacoustic studies in widely diverse populations provided data showing special interactions and associations among the following three levels at which the whistled language practice was observed: the biotope where human whistlers live, the most recurrent social activities using whistled speech and the corresponding whistling techniques. At the end of Chap. 3, we first noted the existence of a transversal influence from the biotope to whistled speech practice that merits further analysis here. First, different constraints inherent in the habitats contribute to the choice of the prevalent activities that are undertaken by the local populations to survive (visual and acoustic constraints, but also time of travel between two points, or vegetation obstacles to pastoralism). In each place, the prevalent activity is associated with an average range of communication which is more conveniently reached by some specific whistling techniques. Table 9.1 shows the types of most common associations around the world, according to our field experience. For example, in the second row, we see that a landscape characterized by dense vegetation favors hunting activities. This statement does not mean that agriculture is not practiced in these landscapes but instead that hunting is the activity that requires the most whistling because of the constraints of distance communication and secrecy of communication toward animals (and in some cases, rival tribes) that are inherent in hunting. Next, we indicate in the third column of the same row which distances are generally covered during hunting communication, and in the fourth column, the most commonly associated whistling techniques. This table also includes, in the last column, examples of language communities for which we described the environmental parameters in Chap. 3 and, therefore, where we could verify these parameters. We note that the singing mode of whistling, which is generally practiced by bilabial whistling or with a tool—a leaf or a flute—does not fit this classification because it is influenced by the relation to music for parts of the whistled repertoire.

Table 9.1 Levels interacting in the ecological niche of human whistlers

Biotope-landscape	Traditional activity	Range	Whistling technique	Example languages (places)
Dense vegetation (forests, savannas)	Hunting	Close, medium	Bilabial, hand	Gavião, Surui, Wayãpi (Amazon)
Mountains with dense vegetation	Hillside agriculture	Medium, long	Labiodental	Mazatec, Chinantec (Oaxaca Mexico)
Cliffy or dry mountains	Herding, hillside agriculture	Very long	Labiodental, digital	Greek (Antia), Spanish (Topares, La Gomera), Turkish (Turkey), Tamazight (Moroccan Atlas)

These observations offer interesting perspectives because they suggest that whistling is strongly structured by different ecological niches and by how human activities are adapted to local biotopes. However, such an interpretation does not imply determinism. On this point, the whistled speech practice provides clear views because it does not exist in all traditional cultures settled in densely forested or mountainous areas. Indeed, concurrent means of communication systems serving similar purposes exist everywhere, such as shouting or visual signaling. Therefore, whistled speech has either disappeared or never been developed in many traditional rural human settlements. Culture is a complex system that may produce self-reflexive or parallel dynamics of evolution. Ecological and biological anthropologists have studied how the physical and biological environment affects traditional cultural practices (e.g, Steward 1955; Hardesty 1972; Bender and Wright 1988; Marshall 1990; Rodning 2010; Kahn 2013).

Where it happens, whistled speech brings new perspectives to the debate because it clearly connects a layer addressing communication techniques with an environmental layer (the habitats in which people live), while showing the key role of a social layer—people and their modes of social organization. Therefore, it emphasizes that *information and communication*, which play important roles as driving forces of cultural evolution in modern societies (Finke 2005, 2006), may have been sometimes deeply impacted throughout history by the environmental contexts in small rural societies. This aspect has been little addressed to date in the literature on human ecology.

We found that some aspects are particularly interesting to consider about the close relation between ecological niche and whistling. For example, as we saw in chap. 4, the recent decline of whistled languages contributes to reveal more clearly how changes in means of communication impact traditional activities. Typically, when the balance established over time by the local populations with an ecological milieu is disrupted by historical factors modifying the main communication means and the local food supply economy, the entire traditional organization of the people is at risk. Crucially, when whistled speech is still present, it signals that traditional activities are still commonly practiced and therefore that traditional knowledge is maintained, including understanding and use of the environment. Whistled speech, then, as a good indicator of the vitality of the traditional way of life is still present, it signals that traditional activities are still commonly practiced and that traditional knowledge using the biological milieu is maintained. Whistled speech, then, is a good human indicator of the vitality of the traditional way of life. Finally, this underscores the emblematic position of the linguistic communities that continue to practice whistled speech: they often live in remote forests and mountains preserved by their isolation and still maintain most of their traditional knowledge and native language; however, this knowledge is clearly at risk because of the rapid invasion of the modern industrial way of life. For the scientific community, this situation represents a tremendous challenge, not only for linguists studying whistling or for anthropologists studying cultural ecology but also for biologists because the ecosystems in which these populations live and that their languages describe with precision remain poorly reported even if they are of diversity for the future of humanity (Loh and Harmon 2014).

9.2 What Animal Whistles May Tell Us About Human Whistled Speech

Numerous animal species employ acoustic communication systems, and some species emit characteristic whistled signals, particularly birds and a few mammals. Human and animal whistles are interesting to compare for many different reasons.

First, human and animal whistles have similar acoustic parameters. Both classes of whistles consist of a narrow frequency band that lasts for a certain amount of time, and the relevant information that the whistles contain resists degradation due to reverberation well (see, for example, Marler 1955; Busnel 1966; Brumm 2004; Oliveira and Ades 2004 about animal whistles). Therefore, both serve a common purpose of distance communication in natural surroundings. However, they may differ in many other respects, e.g., how they are produced and the dynamics of the whistles. For example, at the purely acoustic level, each species shows particular variations in the frequency level or the degree of frequency modulation. These factors enable us to determine which bioacoustic properties of which species are the most relevant to compare to human whistles. Moreover, as we will see here, the nature of information exchanged by naturally communicating whistling animals in the wild as well as the complexity of their productive, computational and perceptual capacities may better inform our understanding of the specificities of language and human whistled speech.

9.2.1 Birdsongs and Whistled Languages

9.2.1.1 Teachings from the Influence of Habitats on Bird Whistles

As we began to see in Chaps. 5 and 6, data from various human cultures show that the whistling techniques used for long-distance speech communication are often lower pitched in dense vegetation than those used in the open valleys of mountains. For example, one of the most popular techniques for long-distance whistling in the Amazonian forest involves hand resonance whistling, which has the effect of stabilizing the whistled frequencies between 1 and 2 kHz (e.g., in the Gavião language of Rondônia; Figs. 1.2, 5.7 and 6.5). Moreover, in the savannas and forests of Burkina Faso, the Gurunsi and Mooré people use wooden whistles (Fig. 2.3, Eboué 1935; Junzo 1998), which have a similar acoustic effect. Finally, as we have explained in Sect. 3.2.2.3 of Chap. 3, Busnel and Classe (1976) have found "dialects" of whistled Spanish "Silbo" on La Gomera characterized only by different ranges of whistled frequencies, with lower frequencies used by people living near the summit of the island, which is much flatter than the rest of the island and is covered by a dense tertiary forest, whereas the rest of the island is very dry and rather cliffy. Therefore, there is evidence suggesting that whistled speech is adapted to the biotope because of the impact of the natural environment on the conveyance of whistled signals.

At this point, the comparison with animal sound communication may be interesting because much more research has been performed on the subject with such signals. In general, it is not rare to observe correlations between environmental constraints and animal acoustic behaviors that are expressed in very diverse ways (e.g., Waser and Brown 1984; Aubin and Jouventin 1998; Mathevon et al. 2004). The "environmental adaptation hypothesis" in bioacoustics applies primarily to acoustic signals used in long-range communication, which are presumed to evolve features that transmit well in the relevant habitat (Morton 1975). This adaptation hypothesis has been more specifically found relevant to consider by the fact that compared to species in open habitats, multiple unrelated bird species in broad-leaved forests use lower frequencies and avoid rapid repetitions of notes (Wiley 2009).

In fact, various differences between the acoustic properties of distinct habitats may provide an explanation for such apparent parallel adaptive behaviors of human whistlers and some bird species. Namely, closed and open habitats result in different attenuation effects (Marten and Marler 1977; Waser and Brown 1986). For example, there is a steeper frequency dependence of attenuation in forest compared with open habitats due to scattering, which increases proportionally with leaf size (Wiley 1991). Moreover, as we have noted in Chap. 6, a frequency window between 1 and 3 kHz was found to be the least susceptible to reverberation in forests (Padgham 2004), which means that it is mostly the upper frequency values of human whistling that are strongly affected by reverberation (in the range of 3–4 kHz) and may contribute to explain why people living in dense forests avoid that upper band. Finally, levels of background noise also differ between habitats. For example, in tropical forests such as the Amazon, the permanent presence of dense populations of noisy insects using frequencies between 2.5 and 5 kHz could also contribute to the need to stabilize whistled speech below this frequency range (see Figs. 6.5 and 6.6 in Chap. 6). Partitioning of the acoustic communication space between species of the same niche has been described among animal species in dense forest habitats (Ryan and Brenowitz 1985; Luther 2008) and it is possible that humans communicating with whistles in the same type of milieu have the same tendency to adjust their whistled frequencies in the least noisy range that they can reach.

9.2.1.2 Other Analogies to/Differences from Human Whistled Speech

There are other parallels between birdsongs and whistled speech that merit attention.

Some of these parallels rely on the acoustic similarity of signals in those systems and on the numerous research studies claiming that songbirds exhibit features of communication that parallel human linguistic communication. From a purely acoustic perspective, some bird species, such as the common nightingale (*Luscinia megarhynchos*) and blackbird (*Turdus rnerula*), produce complex combinations of whistled signals that may resemble and even sometimes exceed in complexity human whistled sentences. At the same time, some parts of these birds' repertoires differ from those produced by humans: bird whistles are generally within a higher frequency range, show much faster rates of change and present more frequent repetition rates of the

same pattern in the same sentence. Birds with such complex whistled signals are generally open-ended learners, in which song acquisition is not confined to an early sensitive period of learning (as occurs for a great many other species of whistling birds, such as the finch and chatfinch), which enables them to develop large repertoires of whistled notes and songs that change over the course of their lives. For example, nightingales belong to the category of birds which only copy conspecifics; whereas blackbirds' songs adapt easily to the signal of other species, including the acoustic dynamics of whistled speech (as testified on La Gomera island where whistlers found instances of their whistled sentences were copied by those birds during past times when the density of human whistlers was higher. This behavior has been replicated in England by Classe (Busnel and Classe 1976)).

The behavioral and neurobiological mechanisms found in bird species reveal other interesting analogous learning and cognitive processes, particularly for child language early development. For example, we find in birds the lateralization of vocal control also found in humans (Nottebohm 1972). Moreover, the phonation controlled through audition in learning birds has a feedback mechanism similar to that of humans (Busnel and Classe 1976). Additionally, several learning whistling birds pass through a period of "subsong" during which the intensity of vocalization is low and the structure of the songs is variable—similar to the stage of babbling in human children (the birds must learn to string notes together as humans do with syllables) (Doupe and Kuhl 1999). Some species also show acoustic variations depending on the environment and the geographical origin of the parents, which are defined as dialectal differences when perpetuated locally (Podos and Warren 2007). Finally, the learning or cognition involved in a song appears to be connected to the number of syllables that birds can remember to put in their songs. This behavioral specialization commonly links to the expansion of appropriate regions of the brain (Moore et al. 2011).

However, in the wild, birds were never found to succeed in associating a sound label with an object, nor do they achieve the complex combinations found in human languages at the semantic or syntactic level that would allow them to change the meaning of a song by changing the combination of notes (Beckers et al. 2012). To date, the absence of evidence for such human-like essential linguistic abilities in songbirds limits the scope of comparison between combinatorial operations made by humans and birds.

9.2.2 Cetacean Whistles and Testing Referential Communication

Cetaceans are among the non-human mammals with the most complex brains for complex cognition. Their study has provided a large body of empirical evidence for complex behavior, learning, sociality, and culture (Marino et al. 2007). Therefore, dolphins are among the most promising non-human animals for testing language-like competencies with whistles. Dolphins emit several different whistle types and

other sorts of signals, such as short pulses with their sonar system. For example, dolphin species, such as the bottlenose dolphin (*tursiops truncatus*), Atlantic spotted dolphin (*stellena frontalis*) and saddle-back dolphin (*delphinus-delphis*), to cite some of the best studied species, produce whistled signals that are sometimes combined in whistled chains that acoustically resemble successions of human whistled short words transposed to higher frequencies. Evidence also shows that the sequential order of whistle production is an important feature of these cetaceans' communication systems (McCowan et al. 1999, 2002). Whistled frequency shapes vary according to the species and range from 4 to 30 kHz (Busnel and Classe 1976). Numerous researchers have tried to classify their variations of frequency in time to contribute to eventually breaking a code leading to some type of semantics. Dolphins can learn, memorize and effectively communicate by exchanging these signals in the wild; however, little is known about how they use these signals. In captivity, dolphins' competency in symbolic referential communication has been proven by their ability to learn to associate novel whistles with objects and use these whistles to report on the presence or absence of the objects. Bottlenosed dolphins can also generalize rules and develop abstract concepts (see reviews in Pack 2010; Janik and Sayigh 2013). Consequently, dolphins have been the subjects of intense scrutiny in the wild to locate evidence of similar abilities, particularly of referential communication. However, it has proved difficult to establish with free ranging animals a valid correlation that could be based on reactions of the receiver to a certain type of signal, except, quite recently, for "signature whistles" in bottlenose dolphins (Janik 2000; King and Janik 2013). The existence of these individually distinctive whistles carrying identity information in their frequency modulation patterns was first discovered in a laboratory (Caldwell and Caldwell 1965). Individuals learn and modify a whistle that they hear in their natal environment to create a novel one for their own identity signature (Tyack and Sayigh 1997). Dolphins also copy signature whistles of others and address the whistle owners with them, both in the wild and the laboratory (Janik 2000).

Several research teams currently seek to exploit in the wild the capacity of dolphins to label individuals to observe whether this ability can also be spontaneously used for objects. For example, since 1985, the team of Herzing has studied in the Bahamas a community of free ranging Atlantic spotted dolphins and bottlenose dolphins which has become habituated to human swimmers. The team is now using a portable electronic device able to produce and recognize some whistles associated with objects, with the objective of teaching these "names" as signature whistles to habituated wild dolphins (Herzing et al. 2012). For the moment, the researchers have used combinations of non-modulated artificial whistles. We argue that it would be ideal to use labels inspired by whistled language so that the whistles would have a linguistic reality for humans. This idea was already suggested by Busnel (1966) and attempted by Batteau (Batteau and Markley 1967) in different circumstances. Batteau's laboratory experiments consisted of conditioning the animals to associate a body motion with an underwater acoustic signal or training the animals to reply with whistles to acoustic signals of great complexity and to imitate them accurately (Markley 1969). Notably, Batteau used electronic whistles

produced by a generator that were transformations of English spoken speech and that closely resembled the productions of non-tonal whistled languages, such as those found in Spanish, Turkish and Greek (except that these whistles ranged between 4 and 12 kHz). One important condition in selecting human-like whistles to address labels to wild dolphins would be to verify that these whistles include fundamental units that are effectively used by dolphins in their repertoire. Interestingly, the fact that the whistles produced during Batteau's experiments were efficient in communicating orders to dolphins already suggests that the dynamics of frequency and amplitude modulations of human whistled speech is relevant to bottlenose dolphins.

9.2.3 Whistling Primates, an Evolutionary Path Towards Human Whistled Languages?

Research on communication competences that imply essential mechanisms for the language faculty has drawn great attention to non-human primates for the simple reason that these animals are closely related to humans. We show here that whistling has an interesting position in this context because it is present in several primate species that have played a key role in comparative research with humans.

9.2.3.1 Gibbons' Songs

Some studies on free ranging primates found evidence for referential and symbolic communication, most of the time related to signaling the presence of predators (Seyfarth et al. 1980; Zuberbühler et al. 1997; Zuberbühler 2001; Fichtel et al. 2005; Arnold and Zuberbühler 2006; Clarke et al. 2006). Among them, only one is an ape, the Gibbon (Hylobatidae) and the signals he uses are clearly whistle-like. Gibbons' songs, comprise loud, melodious, penetrating pure tone modulated calls that have even inspired Darwin in thinking about the possibility of a "musical protolanguage" (Darwin 1871). These calls deserve the denomination of songs because they are produced by the resonance of the vibration of the vocal folds in the vocal tract. They are species-specific and the characteristics that make them so are innate (Geissmann 2000). In their study on referential communication of Gibbons, Clarke and colleagues have found that predator-induced songs were identical to normal songs in the call note repertoire, but that consistent differences appeared in how the notes were assembled into songs with responses that demonstrated that these combinatorial differences were meaningful to the receivers (Clarke et al. 2006).

The production of these modulated tones by Gibbons has attracted attention of other scientists who found that, in Gibbons' songs, as in human speech, neural

dynamic control over the vocal tract configuration, rather than anatomical modifications, is a dominant factor in shaping call structure. This is possible because, in both, the source is independent of the resonance filter of the oral (supralaryngeal) vocal tract that is modified to change the tuning of the tones (Koda et al. 2012). Another interesting aspect shown by this study is that Gibbons' control of their songs resembles the one of human sopranos' (Joliveau et al. 2004) because they tune the oral resonators in a way that amplifies the second harmonic of their voice to project it more loudly. Koda and his colleagues supposed that this acoustical strategy has been selected in response to social and ecological pressures of communicating in the distance in densely vegetated environments.

9.2.3.2 The Special Role of Cotton-Top Tamarins

Another type of advanced approach addressing language-like faculties in whistling primates consists of exploring these primates' ability to pay attention to phonological distinctions of languages and other possible evolutionary precursors to language. For example, Cotton-top tamarin monkeys (*Saguinus Oedipus Oedipus*) have been found to be able to distinguish spontaneously between rhythmically different languages but not between rhythmically similar languages (see Ramus et al. (2000) and Tincoff et al. (2005), based on habituation-discrimination experiments: no training and no reinforcement conditions). They can also discriminate the lowest level of grammar (Fitch and Hauser 2004) defined in Chomsky's hierarchy of formal grammar (Chomsky 1959). Cotton-top tamarins have typically been chosen for these experiments for two reasons: (i) these small primates are easily tested in laboratories and (ii) they have a large repertoire of 38 distinct whistles and chirps (Cleveland and Snowdon 1982) acquired by learning mostly during their youth (Castro and Snowdon 2000). Moreover, these chirps and whistles do not transfer sufficient information in isolation to communicate all of the messages they effectively use, which suggests that they incorporate some type of syntactic rules in areas of their communication (Cleveland and Snowdon 1982; Miller and Ghazanfar 2002). There is also evidence that cotton-top tamarins produce diverse sets of alarm calls that can discriminate between the presence of birds of prey and ground-based predators (Neyman 1978) and that their long calls exhibit individual differences that enable them to identify the caller (Weiss et al. 2001). Similar to our suggestion for dolphins, perceptual studies could be undertaken with human whistled speech stimuli (CV syllables, for example), instead of the ordinary speech stimuli currently used. It would therefore be possible to adapt the whistled speech stimuli to the frequency, amplitude and time variations of call types in those monkeys to test sequences that would seem more familiar to them (for some the experiments suggested by Yip 2006, for example).

9.2.3.3 Orangutans: Whistled Imitations and Leaf Kissing

Two Important Discoveries

Two recent discoveries have revealed that orangutans' (*Pongo pygmaeus* x *P. abelii*) acoustic behavior is important to our subject because these primates can learn whistling without training in captivity and can also use in the wild an acoustic tool, namely a vibrating leaf against the lips.

The first of these studies addresses the spontaneous acquisition of whistling by a zoo orangutan named Bonnie, who most likely was imitating her caretakers (Wich et al. 2009). The authors performed whistling-matching tests showing that Bonnie exerted voluntary control over the duration and number of her whistles. She produced these sounds with the typical bilabial technique also used by humans (and described in Chap. 5). This observation provides evidence that these great apes can learn to produce at least one novel call that belongs to the repertoire of a different species (Lameira et al. 2013a). Moreover, these imitations differ from other voiced or voiceless calls in orangutans in particular, and their mode of production differs from that of other whistling primates in general (except humans). After Bonnie was reported to whistle, ten other captive orangutans known to whistle were identified. The whistling matching tests made with Bonnie have been replicated with the productions of another orangutan. Moreover, articulatory and acoustic whistle characteristics have been compared among three orangutans showing the same control over lips and respiratory musculature, allowing individuals to produce learned voiceless calls (Lameira et al. 2013a). The authors of this study have argued that voiceless call learning in orangutans implies that some important components of human speech learning and control were in place before the Hominid-Pongid evolutionary split.

The other important research was on tool use and its function in one particular call, the kiss squeak, in wild Bornean orangutans (Pongo pygmaeus wurmbii) (Hardus et al. 2009a). The kiss squeak has been described as a sharp intake of air through pursed lips causing a kissing sound (Rijksen 1978) employed as a response to disturbance by potential predators or fear of these predators (e.g., snakes, leopards, tigers, humans) or other orangutans (Rijksen 1978; Hardus et al. 2009a). The kiss squeak is commonly known among orangutans in its unaided form but has been observed in some groups of orangutans to involve a hand or leaf positioned in front of the lips (Peters 2001; Van Schaik et al. 2003; Lameira et al. 2013b). The leaves function as a tool because the orangutans strip them and hold them in one hand against the mouth (Hardus et al. 2009b). Moreover, the observation of all three forms of kiss squeaks in two populations in Indonesia strongly suggests that kiss squeaks on leaves represent a functional innovation that spread locally and became cultural (Lameira et al. 2013b). Indeed, in one location investigated by these researchers, leaf kiss squeaks toward humans did not function to convey body size enlargement—whereas unaided kiss squeaks did—and their use was not related to

perceived threats. This usage contrasted with previous observations of another group of orangutans (at another site) in which, in the same context, orangutan leaf kiss squeaks functionally convey a larger body size and relate to perceived threats (Lameira et al. 2013b). Through the analysis of these observations, the authors of that study have argued that signals involving call production with arbitrary function may date back to the Hominid-Pongid evolutionary split (9–13 mya) and may have paved the way for the use of words with arbitrary meaning in human speech. Moreover, to explain how oral call control found in orangutans might be a precursor to language in humans, Lameira and his colleagues argued that instrumental gesture-calls, such as those observed in leaf-kissing, implied a functional and neural sensory-motor basis that may reconcile gestural and speech evolution models (see the Instrumental Gestural-Call model explained in Lameira et al. 2012).

The fact that orangutans are among our closest relatives gives special significance to these findings. Before these studies, great apes were considered to have poor voluntary control over their vocal tract productions, with the assumption that vocal-fold control was the key innovation enabling humans to develop language. Here, our objective is not to evaluate the plausibility of the models of evolution that the authors propose but to show the parallels that exist between whistled speech and the newly revealed abilities of orangutans.

Convergences with Whistled Speech Practice

The studies on whistling and leaf-kissing orangutans have provided evidence that at least some apes are capable of voluntary oral control and learning in the acoustic domain. Voluntary vocal track control is a key ability because it enables animals to develop communication that is independent of emotional states which is a prerequisite to other advanced language abilities. Therefore, these findings have the potential to place the voiceless sounds controlled by the oral articulators—supralaryngeal vocal tract—at the center of the debate on the evolution of language. Crucially, whistled speech does the same because this practice is inherently and completely characterized by whistled syllables that are essentially articulated in the front of the vocal tract with movements of the jaws, tongue and lips and without any vibration of the vocal folds.

In general, the existence of whistled speech is hardly considered by recent models of language evolution. For example, until now, no mention has been made of whistled speech—including its hand and leaf variants—in the debate analyzing the evolutionary perspectives opened by orangutans' newly discovered abilities. However, among language properties, whistled speech has the rare advantage of being easily compared with such abilities. Indeed, the comparison is significant at several levels: articulation mechanisms, Imitation processes, acoustic features and general functionality of the practice.

First, we note that there are several striking parallels between leaf kissing in orangutans and human leaf whistling: (i) both are found in densely forested areas with individuals in isolation; (ii) both are used to signal a danger, even if leaf whistling in humans is used for several other purposes. (iii) Moreover, we found the same principles of acoustic iconicity and adaptation to distance apply in both orangutans' and humans' use of leaves for communication. Human leaf whistling is a tool-aided iconic realization of normal whistling, similar to orangutans' leaf kiss squeaks in comparison with classical lip kiss squeaks. These practices also have the advantage of favoring sound propagation in the forest by stabilizing sounds at lower frequencies compared to those produced during unaided calls, as was documented in both orangutans (Hardus et al. 2009b) and leaf-whistling human populations of Asia and South America (see Chap. 5 for the technique and Chap. 6 and/or Sect. 9.2.1.1 for acoustic adaptation). However, there is a difference in the control of the leaf vibration: a leaf kiss squeak is atonal (Hardus et al. 2009b), whereas human leaf whistling produces a clearly tonal signal (see Chap. 5) showing more control. All these aspects show common functional uses of leaves for acoustic communication by humans and orangutans in similar environmental conditions. The great diversity of contexts associated to the human practice is the result of a better acoustic control and of a clear and expert control of arbitrariness.

Given the evidence of social learning, fine-tuning and sensory motor feedback in voiceless calls in contrast to voiced calls in orangutans, and given the cognitive abilities of great apes, Lameira, Maddieson and Zuberbühler argued that oral sounds involving facial gestures may have been present from very early stages of language evolution and are likely continuous with some lingual or facial movements used in modern speech. These authors also draw a preliminary conclusion which proposes that protovowels and protoconsonants have evolved separately because spoken vowels are voiced (Lameira et al. 2014). In view of their conclusion, another important feature of whistled speech should be considered in comparative studies exploring the gaps between great ape calls—especially those of orangutans—and human speech: human made whistled vowels function as purely oral sounds showing that humans have developed the ability to represent vocalic sounds with the supralaryngal vocal tract only. This evidence creates the possibility of a common evolution of vowels and consonants from voiceless sounds.

9.2.4 Conclusion on the Comparison of Animal-Human Whistles

We have seen in this section that several characteristics of animal acoustic communication systems inform us of dynamics that might have played an important role in the adaptation of whistled speech to habitats. These characteristics also enable us to improve our understanding of the specificities of human whistled languages compared with animal whistles. We have proposed whistled speech as a tool to

enrich current experimentation protocols developed for testing referential communication or computational abilities in whistling animals. Finally, we have shown that whistled speech is particularly relevant to the debate concerning the evolution of voiceless sounds in primates and humans.

9.3 Conclusion: Questions Raised by Whistled Speech Origin and Evolution

We summarize here the main points that make the practice of whistled speech significant in the evolution and the origin of languages. For example, whistled speech extends to biology the notion of language ecology, which was confined until now to social and political contexts. Next, it shows that whistles are complex enough to transmit the essential aspects of languages, confirming that vocal folds are not compulsory for an acoustic use of the language faculty. Additionally, it proves that vowel and consonant qualities carry a perceptually salient prosodic frequency line, an aspect of prosody that has until now been mostly ignored. Finally, it provides original and new insight into the music-language relation. All these points add important considerations to the evolution of both language and music which are explored in the next subsections.

9.3.1 Whistled Speech and the Environment

As we saw, whistled speech shows adaptations to specific environments and to environmental constraints on acoustic and visual channels of communication. Convergent acoustic properties even suggest that different acoustic environments have exerted differential selective pressures on the development of human whistled languages. Because the advantages of whistling emerge only under particular circumstances that combine social necessity with distant and/or without-sight and/or secret communication and environmental constraints, whistled languages appear to provide a striking case demonstrating the interaction between ecology and language, adding a new biologic dimension to the ecology of languages, previously relevant primarily to language diversity and vocabulary specification (Nettle and Romaine 2000). One of the most original aspects of whistled speech is that this biological dimension has direct repercussions at the phonetic level (Chap. 7). For this reason, whistled speech inspired studies on the impact of the environment on both standard and shouted speech (see Chap. 6 and Meyer et al. 2013). Another original aspect of whistled speech that we saw is that whistled forms of languages are good human indicators of the vitality of traditional knowledge in the cultures where they are still practiced, most of which are situated in hotspots of biodiversity (Chap. 4).

9.3.2 Possible Scenarios of Origin and the Music-Language Relation

9.3.2.1 Monogenesis Versus Polygenesis

To explain the current existence of whistled languages, a first hypothesis is that existing whistled languages are simply the vestigial remains of a widespread ancient phenomenon. The diversity of whistled languages and the ease with which they can be acquired even at a young age show that whistled communication is a universal potential of the human language faculty. This system could have been largely used by prehistoric hunter-gatherers because of its clear advantage for stalking large game with a group or to signal a danger in any type of environment. In this view, whistled languages would not necessarily have been originally linked to particular habitats. Consequently, their current environmentally specific distribution would be only explained by the geographical and cultural isolation provided by these habitats (Nettle and Romaine 2000).

Another possible scenario supported by several observations of our survey is polygenesis. The actual whistled languages are found only in a small minority of languages, however diverse. We have underlined that this rarity is partly explained by the noted erosion of traditional lifestyles; however, it is likely also due to the general relative ease of resorting to shouting to establish long-distance dialogs, with whistled speech requiring more pressure to develop. This argument would be in favor of a key role played by drastic environmental constraints in the emergence of whistled speech, all the more as we found a systematic adaptation of whistled speech (and of its various techniques of production) to typically constraining ecological milieux, which are geographically scattered. Another important aspect of whistled languages is that the spread of whistling practice from one language to another has been found to occur only within the same tonal/non-tonal typological category. There are some proven common origins of whistled speech in historically related communities speaking languages belonging to the same tonal or non tonal category (La Gomera original Guanche Berber and Tamazight Berber of Morocco are related, Mondé languages of Rondônia–Gavião and Suruí, for example—in Brazil are also related, some evidence of the transfer of this practice between different languages was found by Nekitel (1992) in Papua New Guinea) but not when the spoken languages belong to different categories. For example, in the Mazatec Mountains in Oaxaca (Mexico), we observed that the whistlers were attempting to whistle pitch in Spanish. However, when adapting the transposition strategy of their native tonal language to Spanish, they were unsuccessful in transmitting much lexical information because pitch does not discriminate words in Spanish. Therefore, they switched back to the four-tone Mazatec whistled speech to achieve greater intelligibility (cf. Chap. 4). Consequently, this typological barrier, along with the highly localized distribution of whistled languages and the wide geographic distribution and separation of biotopes where they exist, would support

the hypothesis that there must have been several independent local inventions responding to similar constraints: namely, polygenesis rather than monogenesis.

9.3.2.2 Whistling First Versus Voiced Speech?

If we now consider another recent hypothesis that we saw in the section on orangutans: whistling could have evolved even earlier than the hominid hunter-gatherer period. In this case, a learned whistling system would have grown from a limited system of voiceless and orally controlled calls originally used primarily to signal danger and food sources and to reinforce social bonding between isolated individuals in the forest. The system could have originated with the use of a leaf tool, a practice that already shows cultural learning, as well as some elements of iconic imitation and acoustic adaptation to ecological constraints in both orangutans and modern humans (Sect. 9.2.3.3). It is also a practice that may reconcile gestural and acoustic models of language evolution. The hypothesis of developing bilabial whistling is also rendered possible by the fact that captive orangutans are already capable of learning to whistle by imitating humans, both egressive and ingressive ways (Lameira et al. 2013a). One of the most apparent discontinuities between non-human primate communication and human speech concerns repertoire size, and this difference is even greater in great apes than in monkeys or gibbons. In this perspective and in the absence of control of the vocal folds, an early whistled system would have had several advantages. First, it would have easily enabled call-type variation because very different tunes can be obtained with the same technique by simply moving the tongue. Next, it would have enabled the development of both protovowels and protoconsonants that would have been merged in the same whistled frequency shape tuned by the movements of the oral articulator, as it is already the case in formant-based whistled speech (Chap. 7). Interestingly, the few recordings of whistling orangutans provided in Lameira et al. (2013a) show these primates already manage to produce rising and stable tones (see Lameira et al. 2013a). In this speculative but interesting hypothesis of origin, whistling would have been the path for the origin of speech in general and would have preceded and prepared voiced speech.

However, this interpretation is challenged by some observations of this survey. Most crucially, whistled speech now exists in a great diversity of languages where several acoustic, phonetic and phonologic cues support that it is a direct adaptation of voiced speech. For example, the typological distinction between pitch-based and formant-based whistling is easily explained by the preexistence of clearly tonal and clearly non-tonal languages and the existence of two distinct perceptual levels in voiced vowels (pitch and timbre) that are emulated separately in each strategy. These additional arguments favor a precedence of voiced speech on actual forms of whistled speech. If whistling preceded voiced speech, it would have necessarily been reorganized when our ancestors began to control voluntarily the vibration of vocal folds.

We will now explore the music-language relation in whistled speech to see if it provides additional interesting clues to this discussion.

9.3.2.3 Prosody and the Music-Language Relation in Whistled Speech

In his second great book "The Descent of Man and Selection in Relation to Sex", Darwin (1871) addressed the origin of language by presenting a model of "musical protolanguage" that has been widely criticized and supplemented. Recently, Fitch (2010) has emphasized that this model has the advantage of proposing a rich "multi-component" view based on multidisciplinary analyses of biological data with several distinct mechanisms to produce the complex language phenomenon. This model has the particularity to attribute an important role to imitation processes, the control of vocal learning and a common origin of language and music. The importance of these factors for language emergence has been confirmed in more recent models proposed, for example, by Brown (1999) ("musilanguage" model), Falk (2004) ("motherese" model) and Fitch (2010) ("prosodic protolanguage" model), always with a special emphasis on the crucial role of the prosodic aspects of speech.

Whistled forms of languages are eminently prosodic phenomena as they permit the transformation of human voice into simple prosodic signals. However, until now, whistled speech and its related variants used for singing (bilabial or tool-based with either a leaf or a flute) have scarcely been integrated into models of language and/or music evolution. We will therefore conclude this monograph by analyzing what whistled speech would bring to such evolutionary perspectives.

Prosody of Whistled Speech Does Not Emulate Necessarily Voice Pitch

The representation of prosody embodied in the phenomenon of whistled speech may differ drastically from what is commonly accepted in the literature as the essence of prosody, i.e., the fundamental frequency resulting from vocal-fold vibrations. At first contact with whistled speech, non specialists often think that it encodes only the pitch of voice (that is, the *source* in the *source-filter theory* schematically representing the human vocal tract). We saw that encoding fundamental frequency variations of voiced speech in whistles only occurs in pitch-based whistling that primarily selects the suprasegmental characteristics carried by the surface tonal line of tonal languages. In contrast, formant-based whistling primarily selects the vocalic and consonantal qualities, which are shaped by the supralaryngal vocal tract (the *filter*) in what could be called a *segmental pitch.* This selection occurs in most non-tonal languages. The difference depends therefore of the structure of the language that is emulated in whistles. What might be confusing is that whistles are produced the same way in both cases despite the fact that they represent different realities (i.e., pitch and timbre, two different productive levels, also representing two different perceptual attributes of the human brain (see Chaps. 7 and 8)). Consequently,

whistlers perform special gymnastics when listening to whistled dialogs: the receivers' brains will track pitch as pitch in languages with pitch-based whistling; however, they will track pitch as segments in languages with formant-based whistling.

Singing, Instrumental and Talking Whistles

The current theories considering the evolution of language and music together (e.g., Brown 1999; Fitch 2010; Falk 2004) place a major importance on the role of the control of the vocal fold vibrations (which are sometimes called vocalizations in the literature on non-human primates). Therefore, in these models, the reflection on vocal learning is often mostly focused on the emergence of vocal fold control. This focus is likely due to the perception that pitch prosody of voiced speech is the level of language that is the most directly comparable to musical melodies, even in singing. The reality of whistled speech enables and suggests other types of comparisons and considerations.

First, whistled speech allows for rich reflection on the relationship between music and speech because it may exist in both the talking and singing modes of speech in the same culture or in closely related cultures. The simplicity of the signal enables a direct comparison of both modes which are whistled transpositions of spoken and sung voice. Moreover, as we saw in Chap. 5, the singing mode of whistling might be expressed in instrumental forms, either with whistles, flutes or leaves. This adds richness to the notion of singing mode. In these instrumental forms of whistling there is always a song associated to the melody, even it is rarely sung together with the melody played on the instruments (see Sect. 5.4.3). The flute/leaf melody may not evoke a sentence to the naïve listener but the players and the members of the community recall easily the sentences or their lyrics.

A Detailed View of the Music Language Relation From the Perspective of Whistled Speech

According to the observations made in the previous sections, the language-music relationship must be explored in both modes—singing whistles (music) and talking whistles (language)—and in tonal versus non-tonal language.

A first clear difference between singing whistles and talking whistles is in the structure of the whistles: the first type is accomplished with more repetitive and formulaic sentences than the second. Moreover, flute whistles generally show more discrete notes and more stereotyped melodies than for bilabial or leaf whistled singing, partly because the fixed position of the holes results in some additional acoustic limitations.

A second distinction emerges from the contexts of use: the singing mode is a verbal art providing an aesthetic experience in addition to passing a message (most of the time a one-way message to an audience or a lover); whereas the talking mode

is a telecommunication technique for whistled dialogs (two-way communication). For this reason, we did not include the languages that are only known in the sung mode in the maps of Chap. 3 (in the current state of our knowledge, these languages are Aïkana of Rondônia in Brazil, Bora of Western Amazon (Peru, Colombia), Wakuenai of Venezuela, Kuikuro of Brazil (Meyer and Moore 2013) and we recently documented Teko of French Guiana, but there might be many more on other continents than America. All of these involve a flute).

Next, we note that the traditional singing modes of whistling documented so far —whether instrumental or oral—always consist of the emulation of the pitch of the voice, whatever the language (tonal or non-tonal)[1] (Beaudet 1997; Van Der Voort 2010; Franchetto and Montagnani 2011; Hill 2013; Meyer and Moore 2013; Meyer and Moore 2014). The fact that even non tonal languages behave this way while they are mostly based on the emulation of formants in the talking mode, reinforces the idea that the singing mode of whistling, then, is conceptually a different mode of speech emulating the melody of the vibration of the vocal folds, whatever the structure of the language. This has also the following consequences for the music-language relation in whistled speech:

(a) in non-tonal languages, the musical-singing mode of whistling and the talking mode of whistling are very different, the first being based on pitch whistling and the other on formant whistling. The melody of whistled singing is more independent of the phonology in this kind of language, even if it follows closely the number of syllables and the pitch prosody of the vocally sung form.
(b) In tonal languages, the whistled melody follows the phonology of the tonal system both in singing and talking modes because otherwise the lyrics could be altered by changes of meaning induced by frequency variations on the tones. Only a few aesthetic effects are possible in the singing mode (vibrato, changes in the register of the voice) and they do not affect much the fact that important phonological aspects of the language are sung with whistles (see Chap. 5). In this other type of language, the talking mode and the singing mode of whistling are very similar, both based on pitch-whistling.

As a result, we found three different ways of recalling the meaning of the sentences that are uttered in whistles:

(i) In the singing mode of non-tonal languages, the association of meaning with the whistles is formulaic and performed by heart.
(ii) In the singing and talking modes of tonal languages, recalling the meanings of the words and sentences is eased by the tonal phonology mirrored in whistles. The talking mode generally follows the tonal system more precisely. In languages with complex tonal systems, such as Hmong, it is easier to understand the meaning than in simpler tonal systems, such as Suruí of Rondônia.

[1] There are recent attempts to include formant-based whistled speech in musical creations or to try to sing songs with Silbo in La Gomera but they do not reflect the traditional practice.

(iii) The talking mode of non-tonal whistled languages is based on formant emulation, which generally permits the greatest levels of intelligibility.

These different observations highlight that the music-language distinction in whistling is greater in non tonal languages than in tonal languages.

Interestingly, they also allow us to imagine the possibilities of music language distinction if prehominids initially began to control the pitch through their oral articulators only: they would have had less acoustic cues to develop concepts such as music versus language because they would not have had the possibility to distinguish pitch versus timbre. Whistled speech is therefore a real and alive phenomenon showing that the hypothesis of an initial voiceless prosodic protolanguage is coherent with evolutionary theories based on common ancestry for speech and music. It also contributes to show that when our ancestors began controlling the vocal folds, it opened new possibilities of distinctions at several levels: distinctions of tonal and non-tonal forms of languages, but also of music and speech. Both kinds of distinctions have opened the conceptual scope of human language with important consequences for the evolution of whistled speech itself.

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Erratum to: Chapters 1, 7 and 8 in *Whistled Languages*

Erratum to: Chapter 1 in: J. Meyer, *Whistled Languages*, DOI 10.1007/978-3-662-45837-2_1

Figure 1.1 was incorrect due to an error by the publisher and was replaced within the chapter.

Erratum to: Chapter 7 in: J. Meyer, *Whistled Languages*, DOI 10.1007/978-3-662-45837-2_7

In figure caption 7.6 the text "(meaning 'you are welcome')" should read as "(meaning 'you are welcome, what do you want')".

The online version of the original chapters can be found under

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J. Meyer (✉)
Paris, France
e-mail: julmeyer.lab@gmail.com

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Erratum to: Chapter 8 in: J. Meyer, *Whistled Languages*, DOI 10.1007/978-3-662-45837-2_8

Page136: second line of the first paragraph of Sect. 8.2.2.2 ‘whistled speech perception in tonal languages because both types of signals share’ should read as ‘whistled speech perception in non-tonal languages because both types of signals share’.
Page149: the beginning of the second paragraph of Sect. 8.4 ‘Another point about the results obtained by Carreiras and colleagues is that it is possible that the documented left dominance of activations’ should read as ‘Another point about the results obtained by Carreiras and colleagues is that it is possible that the documented left activations’.

Index

J. Meyer, *Whistled Languages*,
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